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UPPER CRETACEOUS COCCOLITHS FROM TEXAS AND EUROPE

DAVID BUKRY

Princeton University, Princeton, New Jersey
Present address: U.S. Geological Survey, La Jolla, California 92037

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ABSTRACT

Electron microscopy reveals a great range of crystallite ultrastructure patterns in the calcite scales of the unicellular marine algae, Coccolithophyceae. These tiny scales, called coccoliths, have been found as fossils in strata as old as 180 million years (Early Jurassic). During the Late Cretaceous, Coccolithophyceae were especially abundant, and their coccoliths were important rock-building constituents. The extensive chalk deposits representing this epoch contain not only large numbers of coccoliths but also a great variety of species. Electron microscopy of samples from this interval reveals fossils of 172 species of Coccolithophyceae. Of these, 94 species are new. Of the 48 genera represented, 11 are new: *Amphizygus, Angulofenestrellithus, Bidiscus, Broinsonia, Costacentrum, Gartnerago, Heteromarginatus, Hexangulolithus, Percivalia, Similicoronilithus,* and *Vagalapilla.*

Special significance is attached to first occurrences, because reworking can extend stratigraphic ranges of these small (1-20 μ) fossils. Last occurrences of groups of species, while less reliable, can also be useful as auxiliary stratigraphic markers when critically evaluated. Two distribution tables are presented, one arranged by stratigraphic first occurrence and the other alphabetically.

Samples examined from Texas were compared to samples from Europe. The bulk of the Santonian-Campanian coccolith floras, in both Texas and Europe, are composed of 41 long-ranging and abundant species. Santonian-age samples contain a total of 105 species; 53 of these appeared first during the Santonian. The succeeding Campanian samples contain 137 species of which 51 are not present in Santonian samples. The evolutionary diversity observed in groups of species with restricted ranges has made it possible to define four new coccolith assemblage zones for the Santonian and Campanian: *Cyclagelosphaera? chronolitha* Zone, *Amphizygus minimus* Zone, *Zygodiscus macleodae* Zone, and *Prediscosphaera germanica* Zone.

INTRODUCTION

This is a monograph based on electron-microscope study of calcareous nannofossils that have been preserved in certain Cretaceous (Santonian and Campanian) marine strata of Texas and Europe. Calcareous nannofossils, called coccoliths, are the skeletal plates produced by golden-brown unicellular marine algae of the class Coccolithophyceae. Coccoliths have been recognized as rock-building constituents in strata ranging in age from Jurassic to Recent.

The flagellated photosynthetic algae of Coccolithophyceae are among the most abundant organisms in the sea. They are generally less than 50 μ in diameter, and their skeletal plates are 1 to 20 μ diameter. EHRENBERG first illustrated coccoliths in 1840. These first figures were of fossil forms from chalk, but EHRENBERG considered them to be inorganic. HUXLEY, in 1858, discovered coccoliths in deep-sea sediments. However, the nature of coccoliths as the constituent plates of spheres (coccospheres) was first noted by WALLICH in 1860. In 1891, MURRAY & RENARD in reporting on the voyage of the H.M.S. *Challenger* recognized coccospheres as parts of living pelagic algae. LOHMANN did the first extensive taxonomic work on living forms in the early 1900's. Until the early 1950's, work on living and fossil Coccolithophyceae was largely carried on by three men, SCHILLER, KAMPTNER, and DEFLANDRE.

Two developments in the early 1950's gave the study of coccoliths new significance and initiated new interest in the field. Though only the coarse structure of coccoliths is discernible in light microscopy, BRAMLETTE & RIEDEL were able to demonstrate that coccoliths could be used stratigraphically. The second important development was the application of electron microscopy to the study of coccoliths by DEFLANDRE & FERT in Paris and by BRAARUD and co-workers in Oslo. Even though these early studies were done by direct transmission, which yielded essentially only outlines of coccoliths, they did reveal new levels of structural complexity. By 1957, DEFLANDRE and DURRIEU had successfully used carbon replicas to study surface details of coccoliths. BLACK & BARNES, and HAY & TOWE had developed excellent separation and replication techniques for electron microscopy of fossil coccoliths by the early 1960's. The work of BRAMLETTE & SULLIVAN in California and HAY & SCHAUB in Switzerland demonstrated a useful zonation for the Lower Tertiary based on the Coccolithophyceae content of detailed section collections.

Major survey works on Upper Cretaceous coccolith assemblages in Texas (GARTNER, 1968) and Europe (STOVER, 1966) defined many new taxa and outlined evolving assemblages.

At this stage of development, coccoliths are just beginning to be used for purposes of stratigraphic zonation and correlation, but they promise to become important stratigraphic tools. Detailed floral descriptions based on systematic collecting of sections must be made; and comparisons must be made with sequences elsewhere. This paper describes the coccolith floras of the Santonian-Campanian of Texas, and their detailed stratigraphic distribution. Reference samples from Nebraska and Europe, studied by the same methods, are compared, and possible correlations are discussed.

ACKNOWLEDGMENTS

My first introduction to calcareous nannofossils came through work being done at Princeton University on fine-grained limestone by ALFRED G. FISCHER, ROBERT E. GARRISON, and SUSUMU HONJO. STEPHEN F. PERCIVAL, of the Socony Mobil Research Laboratory, suggested that the Austin Chalk would be a good unit to study for Upper Cretaceous coccoliths and helped in collecting samples. WILLIAM W. HAY, University of Illinois, gave advice on the paleontology of coccolithophorids and provided reference samples from European localities. Electron microscopic work was done by me at the Central Electron Microscope Laboratory of the University of Illinois, directed by B. VINCENT HALL. Completion of research and writing at Princeton was supported by a Socony Mobil Fellowship and by a Petroleum Research Fund Fellowship (grant 1114-A2) provided by the American Chemical Society.

I especially thank A. G. FISCHER and W. W. HAY for advice and guidance during the preparation of this study, which was a Ph.D. dissertation at Princeton University. Valuable discussions with ROBERT C. HANDFIELD, JAMES E. BROOKS, ROBERT E. GARRISON, STEFAN GARTNER, JR., ROBERT H. HANSMAN, SUSUMU HONJO, BRUCE A. MASTERS, GEORGE W. MOORE, and EMILE A. PESSAGNO are appreciatively acknowledged. I wish to thank RAYMOND C. MOORE for many suggestions on manuscript style and for editorial improvements. Finally, I acknowledge the generous financial support of the University of Kansas and the Petroleum Research Fund grant 1114-A2 of the American Chemical Society in the publication of this monograph.

MORPHOLOGICAL TERMINOLOGY

abcentral. Inclination of surface (element or rim) away from center point of coccosphere.

adcentral. Inclination of surface (element or rim) in toward center point of coccosphere.

arm. Portion of crossbar between rim and center of coccolith.

bar. Skeletal element crossing central area that does not pass through center of coccolith.

block. Cubical or tabulate coccolith element.

central area. Part of coccolith enclosed by rim cycle.

coccolith. General term for any calcified skeletal element of Coccolithophyceacae having heliolithid structure or other complex construction.

coccolith center. Center of coccolith symmetry in proximal and distal view.

coccolithophore. Any chromatophore-bearing protist which at some phase of its life cycle produces coccoliths.

coccosphere. Entire spherical test of a coccolithophore, composed of interlocking coccoliths.

crystallite. Largest structural unit acting as single crystallographically homogeneous domain. These units lack the true crystal form of their constituent mineral—calcite.

cycle. Ring of skeletal elements.

clockwise inclination. With sutures of elements inclined rightward as they proceed to periphery.

counterclockwise inclination. With sutures of elements inclined leftward as they proceed to periphery.

dextral imbrication. Each element overlapping one to right when viewed from center of cycle.

distal view. Outward-facing convex side of coccolith.

eccentricity. Measure of variance of coccolith outline from perfect circle: long axis/short axis.

element. Basic structural unit of coccolith, skeleton consisting of single calcite crystallite.

lath. Skeletal element with one large dimension, one intermediate, and one very small.

proximal view. Inward-facing concave side of coccolith.

radial. Suture corresponding to radius in circular form or to straight line drawn through nearest focus or line connecting foci of elliptical form.

rim. Peripheral cycle or cycles of elements in coccolith skeletons surrounding central area.

secondary cycle. Accessory circlet of elements which instead of being concentrically within rim cycle rests on rim cycle, seen only in proximal view.

shield. Single layer of elements forming entire coccolith surface.

sinistral imbrication. Each element overlapping one to left when viewed from center of cycle.

stem. Complex of elements in form of cylinder or prism, which may be hollow or solid, and extends from center of distal side of some coccoliths.

suture. Boundary between skeletal elements.

SAMPLING

A total of 122 samples were taken from the Eagle Ford Shale, Austin Chalk, and Taylor Marl of Texas. These samples were collected from 17 localities in the vicinities of Dallas, Waxahachie, and Austin. Measured sections were available for 7 localities and were made for the other localities. A sample interval of 5 to 10 feet was used. Twenty-four reference samples from Europe and from Knox County, Nebraska, were not collected personally.

In order to preserve valid first-occurrence information, sampling was done from the base to the top of sections at each locality. Samples were stored in plastic bags and sealed.

Sections sampled at various localities are identified in the letter- or letter-and-number-coded list given below. Samples at each place are identified by numbers (e.g., #1, #2). The letter "c" stands for chalk lithology and "m" for marl. The interval in feet between samples is indicated by numerals between dashes (e.g.,—10′—); thus Base #1c—10′—#2c Top, means that the two chalk samples taken at a specified locality are stratigraphically 10 feet apart.

Sample Localities

Description

Localities

ALB—Type lower Albian (marl); Dienville, France, under the bridge over the Aube River. Collector: W. W. Hay. [Reference: Geological Survey of France, Geologic Map of France, Map 83 (1-80,000).]

B-8—Craie de Meudon (chalk), middle? Campanian, ***Belemnitella mucronata*** Zone, Meudon, France. Collector: W. W. Hay.

B-15—Type middle Senonian (chalk), ***Belemnitella quadratus*** Zone in the big quarry behind the railroad station, at Sens, France. Collector: W. W. Hay.

B-22—Aachen marl, middle Campanian, ***Belemnitella quadrata*** Zone, Aachen, Germany. Collector: W. W. Hay. The *B. quadrata* Zone precedes the ***B. mucronata*** Zone. [Reference: Breddin, Bruhl, and Dieler, 1963, Geol. Mitt., v. 1, nos. 2-4, Aachen.]

C—Lower Austin Chalk (marl and chalk), early Coniacian; stream bank at foot of Jewel Street, Austin, Texas. [Reference: Stop #9 of the Corpus Christi Geol. Soc. Guidebook to the Austin area 1955, also, Bureau of Economic Geology Loc. 226-T-45.] Five samples were collected. Sample #*b* is a marl at the Eagle Ford contact. (Base, #*Bm*—0.5′— #*1c*—1′— #*2c*—1′— #*3c*—1′— #*4c*, Top).

F-14—Type Campanian marl, along roadside, highway N 10 (east branch) at south side of Barbezieux, France. Collector: W. W. Hay.

KG-11—Kjölby Gaard chalk, Maastrichtian, 11 m. below Danian sediments, Kjölby Gaard, Denmark. Collector: W. W. Hay.

LW—Lower Taylor Marl and upper Austin Chalk, early Campanian and middle Santonian, respectively, in gully and spillway cut at the bridge on Farm Road 877 over the spillway of Lake Waxahachie, Ellis County, Texas. [Reference: Personal communication from Robert Slaughter of Southern Methodist University.] Four samples were collected: *LW-1* in chalk 11 feet below contact; *LW-2* in chalk, just below contact; *LW-3* in marl, just above contact; *LW*-4 in marl, 5 feet above contact.

N—Niobrara Formation (chalk) and Pierre Shale, Coniacian to Santonian; from type locality in Knox County, Nebraska. Collector: unknown; provided by B. A. Masters. [Reference: Wilmarth, M. G., 1938, USGS Bull. 896, pt. 2, p. 1500.] Four samples available; #*0* is a chalk from the base of the Niobrara Formation. (Base, #*0c*—70′— #*7c*—30′— #*100c*—8′— #*11+8m* [Pierre Shale sample], Top).

PB—Upper Austin Chalk (chalk), middle Santonian; stream bank at Buckner Boulevard and Peavy Avenue, Dallas, Texas. [Reference: Personal communication from Robert Slaughter of Southern Methodist University that the chalk here had recently been determined as being 50 feet below the top of the Austin Chalk at Dallas.]

PH—Lower and middle Austin Chalk (chalk and marl), early Santonian; stream-cut and roadcut between Greenville Avenue and Presbyterian Hospital, Dallas, Texas. [Reference: Hall, G. W. B., 1953, Field and Laboratory, v. 21, no. 3, p. 104-111.] Described as a 40-foot transitional section. 11 samples were collected; #*1* at stream level. (Base, #*1c*—4′— #*2c*—1′— #*Bm* [middle marl]—3′— #*4m*—3′— #*5c*—3′ #*6m*—2′— #*7m*—5′— #*8c*—20′— #*9c*—5′— #*10m*—5′— #*11m*, Top).

PS—Lower Austin Chalk (marl and chalk), early Santonian; stream-cut and fresh roadcut on Polk Street at Five Mile Parkway, Dallas, Texas. 11 samples were collected; #*A* is from the lowest chalk exposed. Base, #*Ac*—5′— #*Bm*—4′— #*Cc*—20′— #*1c*—6′— #*2m*—7′— #*3m*—3′— #*4m*—3′— #*5c*—4′— #*6c*—9′— #*7m*—11′— #*8m*, Top).

PT—Lower Austin Chalk and Middle Marl (chalk and marl), early Santonian; stream-cut, Ten Mile Creek at Pleasant Run Road, South Dallas County, Texas. [Reference: Williams, T. E., 1957, Field and Laboratory, v. 25, nos. 213, p. 37-46, Section 9.] 14 samples were collected; #*8* is at the base of the section (165-foot level of Williams). (Base, #*8cm*—10′— #*1c*—10′— #*2m*—10′— #*3c*—5′— #*4m* middle marl 5′— #*5cm*—5′— #*6m*—5′— #*7m*, Top). In fault block: (Base, #*9c*—5′— #*10c*—6′— #*11m*—6′— #*12c* middle marl—9′— #*14m*—5′— #*13c*, Top).

Q—Lower Austin Chalk (chalk and marl), early Santonian; quarry face of Lone Star Cement Company on south side of the Fort Worth Turnpike, about 0.5 mile west of Hampton Road, Dallas, Texas. Ten samples were collected; #*2* is from the basal chalk ("bone bed") at the Eagle Ford Shale contact. (Base, #*2c*—3′— #*3c*—15′— #*4c*—7′— #*5m*—8′— #*6c*—7′— #*7m*—8′— #*8m*—3′— #*9m*—6′— #*10m*—3′— #*11c*, Top).

S—Lower Austin Chalk (chalk and marl), early Santonian; Farm Road 1382, west of Straus Road, South Dallas County, Texas, [Reference: William, T. E., 1957, Field and Laboratory, v. 25, nos. 2-3., p. 37- 46, section 20.] 11 samples were collected at this section; #1 is a chalk at the 20-foot level of Williams (20 feet above the Eagle Ford Shale contact). (Base, #*1c*—10′— #*2c*—7′— #*3c*—2′— #*4c*—8′— #*5m*—12′— #*6c*—2′— #*7c*—11′— #*8cm*—15′— #*9cm*—10′— #*10m*—6′— #*11c*, Top).

SF-10—Type middle Santonian (chalk), locality of the type Santonian visited by the Colloque de Micropaléontologie, at place where the railroad Saintes-Saujon crosses D-128, 3 km. south of Saintes, France. Collector: W. W. Hay.

SF-11—Type middle Santonian (marl), beneath water tower at intersection of Rue des Anemones and N-137, Saintes, France. Collector: W. W. Hay.

WR—Upper Austin Chalk (chalk), early to middle Santonian; White Rock Road at Shook Avenue, Dallas, Texas. (*Gryphaea wratheri* Zone, about 180 feet below top of Austin Chalk). [Reference: Foscue, E., *et al.* (ed.), 1941, Field and Laboratory, v. 10, no. 1, p. 1-134.]

42—Upper Austin Chalk, upper "Dessau" member (chalk), middle Santonian; stream-cut along Walnut Creek, just north of bridge on Route 290, Austin, Texas. [Reference: Stop #10 of Corpus Christi Geol. Soc. Guide book to the Austin Area

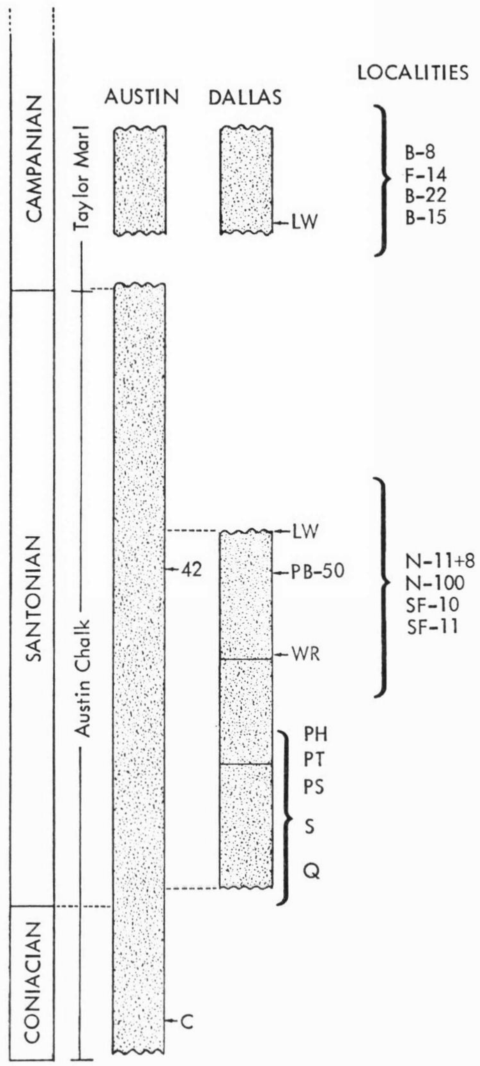

FIG. 1. Stratigraphic positions of studied samples and their interrelations

[Sections within the lower and middle Austin Chalk at Dallas are related by the approximate equivalence of samples PT-6 to PH-8, PS-8 to PT-8, S-8 to PSA, and Q-4 to S-1.]

1955, also, Bureau of Economic Geology Loc. 226-T-42. 3 samples were collected. Sample *#q* is from the top of the "Dessau" member. (BASE, *#ac—28'— #fm—2'—gc,* TOP).

The determined stratigraphic positions of studied samples and their relations to one another are shown diagrammatically in Figure 1.

PREPARATION OF SAMPLES

The outer surface of samples was shaved to help eliminate possible contamination. Approximately 1 cc. of sample was placed in a beaker. Distilled water was added until a depth of 3 to 6 cm. was obtained. The beaker was placed in a jeweler's sonicator for 10 minutes at moderate vibration level. Afterward, the beaker was allowed to sit undisturbed for 1 to 2 minutes. During this period the coarse noncoccolith fraction settled to the bottom. The decantant, containing the coccolith fraction, was then carefully poured into a second beaker. This beaker was covered and kept undisturbed for 10 to 12 minutes. Then the decantant was poured off carefully. The remaining deposit at the bottom of the beaker was the coccolith-size fraction consisting of 1 to 20 μ particles. This fraction was resuspended in a little distilled water and placed in small plastic vials.

For electron-microscope examination, the vials were first agitated by hand and sonicator to "homogenize" the distribution of the coccolith fraction. A few drops of the fluid were extracted by pipette and placed onto a freshly cleaved mica surface. A heat lamp was used to dry the preparation, which then was placed in a vacuum evaporator. Metal shadow (platinum or chromium) was evaporated at a 30-degree angle above the horizontal. Next, a thin replicating film of carbon was evaporated. A slight "back-shadowing" effect was used by having the carbon evaporation come from an 80- to 90-degree angle above the preparation but behind it with respect to the metal shadow direction. When removed from the evaporator, the mica and film surface was scored with a razor into electron microscope support grid sized areas. The film was removed by carefully submerging the mica at a 45-degree angle into a crystallizing dish of distilled water. Surface tension of the water stripped off the film, which then was treated with a weak hydrochloric acid bath and a strong hydrofluoric acid bath. These baths removed the calcareous and siliceous particles which had been shadowed and replicated. The shadowed carbon film was then picked up on 200-mesh copper electron microscope grids.

MATERIALS AND STUDY PROCEDURES

Grids were systematically scanned and photographed using the RCA-2C, RCA-2E, and JEM-7 model electron microscopes. Most of the 5,400 electron-micrographs were made with the RCA-2E which produces 2 × 2 inch negatives. Dupont, high contrast, Cronar Ortho A sheet film was used for these negatives.

Several preparations of each sample were made. Several grids from each preparation were examined in the electron microscope. Samples found to be well preserved and to have a diverse flora were photographed extensively —20 to 100 grids examined. Photographic preference was given to new forms and isolated, well-preserved forms. Full-sheet enlargements of 1,000 selected forms and 2 × 2 inch contacts of all negatives were used for study and description purposes.

TYPES

In preparing coccolith samples for study, the actual nannofossils are either destroyed or cannot be relocated.

Since the calcite composing coccoliths is opaque to the electron beam of the electron microscope, a replica technique is employed and the coccoliths are dissolved in hydrochloric acid. Mobile mounts provide the most information about coccoliths in the light microscope. Here the coccoliths are suspended in a silicone oil so they can be rotated and studied in various views. In either case, the only preservable record of a species is a photographic negative. Therefore, these photographic and electron-micrographic negatives are designated as types. A repository for such types has been established at the Geology Department of the University of Illinois, Urbana, Illinois. Types of the species described in this dissertation are deposited there with catalog numbers UI-H-2768 through UI-H-3629.

Coccoliths have different structural patterns in proximal and distal views. Since only one negative can be designated a holotype, representing a single specimen, only one of the two views can be used as holotype. However, to characterize a new species adequately a specimen best showing the characteristics of the opposite side should also be designated. Such a specimen is a member of the paratype suite of the new species. For convenience of other workers it is informally designated as a primary paratype.

Living coccolithophores are classified on the basis of the shape and structure of their coccosphere and constituent coccoliths. Therefore, living genera are based on the skeletal structure of the whole plant. Coccospheres discovered as fossils are therefore considered to be true genera. However, the main fossil evidence of coccolithophores is a wealth of isolated coccoliths. Since the true genus of the whole organism that produced these coccoliths cannot be adequately described, these forms are assigned to organ genera. A third generic category is the form genus which contains disaggregated specimens lacking natural affinities to other groups.

DISCUSSION

STRATIGRAPHIC DISTRIBUTION

While last occurrences and abundances of coccoliths can be stratigraphically useful, the possibility of these small microfossils being reworked dictates that first occurrences are most reliable for stratigraphic purposes. Tables 1 and 2 record these for the 94 new species and subspecies described here. Table 2 and Appendix 1 show more species appearing during deposition of the lower Austin Chalk than during deposition of the middle and upper Austin Chalk. A similar large number of new species is shown by the lower Taylor Marl samples. However, in the lower Austin and lower Taylor the large number of first occurrences may be attributed to forms that evolved during time represented by the Eagle Ford-Austin and Austin-Taylor unconformities.

Samples from Texas were related to European stages using the Upper Cretaceous Correlation Chart of E. A. Pessagno (1966) which was based on planktonic foraminifers. Though the most extensive coccolith examinations were done on chalk and marl deposits in the Dallas, Texas area, samples from Austin, Nebraska, France, Denmark and Germany were also examined for their coccolith content. In the Dallas area the Austin Chalk is bounded unconformably by the underlying Eagle Ford Shale and overlying Taylor Marl. The Austin Chalk is divided into three members, lower chalk or "Atco," middle marl or "Bruceville," and upper chalk or "Hutchins," each about 200 feet thick. Reference samples of the Senonian Niobrara Formation and Pierre Shale from the type locality of the Niobrara in Nebraska were examined. Also studied as references were samples from the Austin Chalk of Austin, Texas; type lower Albian gray marl from Dienville, France; type middle Santonian marly chalk from Saintes, France; middle? Campanian Craie de Meudon from Meudon, France; type middle Senonian chalk from Sens, France; type Campanian marl from Barbezieux, France; middle Campanian Aachen Marl from Aachen, Germany; and Maastrichtian Kjölby Gaard Chalk, from Kjölby Gaard, Denmark.

Of 105 species observed in the lower to middle Santonian samples, 24 species are restricted to this interval. Mostly from the Austin Chalk, these 24 are all new species. The occurrences of the total 172 species reported in this study are presented in 2 tables. Table 1 represents the complete distribution of species within the samples studied. Table 2 records the taxa described in order of first occurrences.

GEOGRAPHIC DISTRIBUTION

As pelagic organisms, coccolithophore species have comparatively wide distribution. ***Emiliania huxleyi*** (Lohmann) Hay & Mohler, for example, is known from all oceans in the tropics, subarctic, and subantarctic. Other species, however, are more limited, and low-latitude coccolithophore floras are more diverse than are high-latitude ones (Hasle, 1960).

Distribution of coccoliths is not necessarily limited to the areas where certain species live. Hay (1963) noted that "Coccoliths settle much more slowly than the tests of planktonic foraminifera and the boundaries of coccolithophore provinces (if they exist) are obscured." However, Recent studies by McIntyre (personal communication)

TABLE 1. *Distribution of Coccolith Species Alphabetically Arranged in Samples Studied from Various Localities in Stratigraphic Sequence from Albian (ALB) to Maastrichtian (KG-11).*

	CONI.		SANTONIAN																						CAMPANIAN							
ALB	C-4	N-0	S-1	S-2	Q-6	S-3	S-4	S-6	PSA	S-10	S-11	PS-1	SF-11	SF-10	N-100	PT-6	PH-8	WR	42a	42g	PB-50	LW-1	LW-2	N-11+8	LW-3	LW-4	B-15	B-22	F-14	B-8	KG-11	LOCALITIES and SAMPLES in stratigraphic sequence from Albian (ALB) to Maastrichtian (KG-11)
-	-	-	-	-	-	•	-	-	-	•	-	-	•	-	-	-	-	•	•	-	•	•	•	-	-	•	-	-	-	•	-	*Amphizygus brooksii brooksii
-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	•	-	*A. brooksii nanus
-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	*A. minimus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	•	-	-	-	-	•	-	*A. papillatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	•	-	*Angulofenestrellithus snyderi
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	Anoplosolenia brasiliensis
•	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	•	-	-	-	-	•	-	-	•	•	-	-	-	•	-	Apertapetra gronosa
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	Arkhangelskiella cymbiformis
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-	-	-	-	-	-	-	-	-	-	-	•	•	•	-	•	-	-	•	•	-	•	•	•	-	•	•	-	•	•	•	-	*Bidiscus cruciatus cruciatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	-	•	•	-	•	-	-	-	*B. cruciatus multicruciatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*B. monocavus
•	-	-	•	-	-	•	•	-	-	•	-	-	•	•	•	•	-	•	•	-	-	•	•	-	-	•	-	•	•	•	-	*B. rotatorius
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-	-	-	•	•	•	•	-	-	-	•	•	-	•	-	-	•	•	•	•	-	•	•	-	•	•	•	•	•	-	•	-	B. testudinarium
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*B.? ethmoquadrata
-	-	-	-	-	-	-	-	•	-	-	•	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	*B. furtiva
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	*B. handfieldii
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-	-	•	•	-	-	•	•	-	•	-	-	-	-	-	•	•	•	•	•	-	•	•	-	-	•	•	-	•	-	•	-	Chiastozygus amphipons
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*C. garrisonii
-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	•	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*C. interruptus
-	-	-	•	-	-	•	•	-	-	•	•	-	•	•	•	•	-	•	•	•	•	•	•	-	-	-	-	•	-	•	•	C. inturratus
-	-	-	-	-	-	•	-	-	-	-	•	-	-	-	-	•	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-	*C. planus
-	-	-	-	-	-	•	-	-	-	•	•	-	-	-	•	-	-	-	•	-	-	-	-	-	•	•	-	-	-	-	-	C. plicatus
-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*C. propagulis
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	•	•	-	-	-	-	-	*C. synquadriperforatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*Corollithion ellipticum
-	-	-	•	-	•	•	•	-	•	•	•	-	-	-	•	-	-	•	•	-	-	-	-	-	-	•	-	•	-	•	-	C. exiguum
-	-	-	•	-	•	-	•	-	•	-	-	-	-	-	•	-	•	•	-	•	-	-	-	-	-	•	-	•	-	•	-	C. rhombicum
•	-	-	•	•	-	•	•	-	•	-	•	-	-	-	•	•	•	•	•	-	•	•	•	•	•	•	-	-	-	•	-	C. signum
-	-	-	•	•	-	•	•	•	•	-	-	•	-	-	-	-	-	•	•	-	-	-	-	-	-	•	-	-	-	-	-	Costacentrum horticum
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•	-	-	-	-	-	-	•	-	-	-	•	•	-	-	•	-	-	-	•	-	•	-	-	-	-	•	-	-	-	-	-	Cretarhabdus conicus
•	•	•	•	•	•	•	•	•	•	•	•	•	•	-	•	•	•	•	•	•	•	•	•	-	•	•	-	•	•	•	•	C. crenulatus crenulatus
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	•	-	*C. multicavus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	C. loriei
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-	-	-	-	•	•	•	-	-	-	-	•	-	•	-	-	-	-	-	-	-	-	-	•?	-	-	-	-	-	-	-	-	C. unicornis
-	-	•	•	-	-	•	•	•	•	•	•	•	•	•	•	-	•	•	•	•	•	•	•	-	•	•	-	•	-	•	•	Cribrosphaera ehrenbergi
-	-	-	•	•	-	•	•	•	•	•	•	-	•	•	•	-	•	•	•	•	-	•	•	-	-	-	-	•	-	•	•	C. laughtoni
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	C. pelta
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*Cyclagelosphaera baticlypeata
-	-	-	•	-	•	•	-	-	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*C.? chronolitha

indicate that important quantities of coccoliths do reach the ocean floor directly from the overlying water mass. Rapid sinking is accomplished via fecal pellets of zooplankton.

Upper Cretaceous dominant species, such as *Watznaueria barnesae* (BLACK), *Eiffellithus turriseiffeli* (Deflandre) REINHARDT, and *Cretarhabdus crenulatus crenulatus* BRAMLETTE & MARTINI are found in practically all samples from Nebraska, Texas, and Europe. In fact, of 49 Santonian-Campanian species that were found to be

TABLE 1. *(Continued.)*

	CONI.		SANTONIAN																						CAMPANIAN							
ALB	C-4	N-0	S-1	S-2	Q-6	S-3	S-4	S-6	PSA	S-10	S-11	PS-1	SF-11	SF-10	N-100	PT-6	PH-8	WR	42a	42g	PB-50	LW-1	LW-2	N-11+8	LW-3	LW-4	B-15	B-22	F-14	B-8	KG-11	LOCALITIES and SAMPLES in stratigraphic sequence from Albian (ALB) to Maastrichtian (KG-11)
•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	C. margereli
-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	•	-	-	-	-	-	-	-	•	-	*C. rotaclypeata
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*C. specioclypeata
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*Cyclococcolithus? waxahachia
-	-	-	•	-	-	•	-	•	-	•	•	-	-	-	•	-	-	-	-	•	-	•	-	-	-	•	-	-	-	-	-	*Cylindralithus asymmetricus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	•	-	-	-	-	-	*C. biarcus
-	-	-	•	-	-	-	•	-	•	•	•	•	-	-	-	-	•	•	-	-	-	-	-	-	-	•	-	-	-	-	-	*C. coronatus
-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*C. nudus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*C. sculptus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	C. serratus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	*Discoaster ? hayi
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*D. ? noelae
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	*Discolithina ? furlongii
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	*D. ? hallii
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	*D. ? pagei
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-	-	-	•	•	•	•	•	-	•	-	•	•	•	-	•	•	-	•	•	•	•	•	•	-	-	•	-	•	•	•	•	E. turriseiffeli
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	•	-	•	-	*Ethmorhabdus camaratus
-	•	-	•	-	•	•	•	•	•	•	•	•	-	-	•	•	•	•	•	•	•	•	•	-	-	•	-	•	-	•	-	Gartnerago concavum
-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	G. costatum costatum
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*G. zipperum
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	*G. sp.
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*Heteromarginatus wallacei
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•?	•	-	-	-	-	-	-	-	-	-	-	-	-	*Hexalithus gardetae
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	*Hexangulolithus primus
-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	Kamptnerius magnificus magnificus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	-	•	•	*K. magnificus sculptus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*K. percivalii
-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	K. punctatus
-	-	-	•	-	-	•	•	-	•	-	-	•	-	-	-	•	•	-	-	-	•	-	-	-	-	-	-	-	-	•?	-	Lithastrinus floralis
-	-	•	-	-	-	-	•	-	-	•	-	•	-	-	•	-	-	•	-	-	-	-	-	-	•	•	-	-	-	-	-	L. grilli
•	•	-	•	-	-	•	•	-	•	-	•	•	-	-	•	•	•	•	-	-	-	•	•	-	•	•	-	•	-	•	-	Lithraphidites carniolensis
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	*L. grossopectinatus
-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	•	-	-	-	•	-	-	-	-	-	•	•	•	-	-	-	Lucianorhabdus cayeuxi
-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	•	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	Marthasterites furcatus furcatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	-	-	-	-	-	M. furcatus crassus
-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*M. furcatus simplex
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M. jucundus
-	-	•	•	-	-	•	•	-	•	•	-	•	•	-	•	•	•	•	•	•	•	-	•	-	•	•	-	-	-	•	-	Microrhabdulus belgicus
-	-	•	-	-	-	-	•	-	•	-	•	-	-	-	•	•	-	•	-	-	-	-	-	-	•	•	-	-	-	•	•	Micula decussata decussata
-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	•	-	-	•	-	-	-	-	-	-	-	•	-	-	-	-	-	M. decussata concava
-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*Nannoconus farinaccae
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	Nephrolithus gorkae
-	-	•	•	-	•	•	•	•	•	-	•	•	-	-	•	•	•	-	•	-	•	-	•	-	-	•	-	•	•	-	-	Parhabdolithus angustus
-	-	-	-	-	-	-	-	-	•	-	•	•	-	-	-	•	•	•	•	•	•	-	•	-	-	•	-	•	-	•	-	*P. fischeri
•	-	-	•	-	-	-	•	-	•	•	•	•	-	-	•	•	•	-	•	-	•	•	•	-	-	•	-	-	•	•	-	P. granulatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	P. regularis
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*Percivalia pontilitha
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*P. porosa
-	-	-	-	-	-	•	•	•	-	-	-	-	-	-	•	-	•	•	-	-	•	-	-	-	•	•	-	-	-	•	-	Podorhabdus dietzmanni
-	-	-	•	•	-	•	-	-	-	-	-	-	-	-	-	-	-	•	-	-	•	-	-	-	-	•	-	-	-	-	-	P. granulatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*P. reinhardtii
-	-	-	-	-	-	•	•	-	•	-	-	-	-	-	•	-	-	•	•	-	•	-	-	-	•	•	-	-	-	-	-	*P. quadriperforatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*Pontilithus complexus
-	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P. obliquicancellatus

especially abundant, 41 are common to both Texas and Europe. Through electron microscopy, the identification of many small and nondominant species has provided a more complete picture of floral distributions.

EVOLUTION

The large coccolith flora of the Austin Chalk theoretically provides an excellent basis for correlation with coccolith assemblages elsewhere, but only when other

TABLE 1. *(Continued.)*

	CONI.		SANTONIAN																						CAMPANIAN							
ALB	C-4	N-0	S-1	S-2	Q-6	S-3	S-4	S-6	PSA	S-10	S-11	PS-1	SF-11	SF-10	N-100	PT-6	PH-8	WR	42a	42g	PB-50	LW-1	LW-2	N-11+8	LW-3	LW-4	B-15	B-22	F-14	B-8	KG-11	LOCALITIES and SAMPLES in stratigraphic sequence from Albian (ALB) to Maastrichtian (KG-11)
-	●	-	●	-	●	●	●	-	●	●	●	●	●	-	●	●	●	●	●	●	●	●	●	●	●	●	-	●	●	●	●	Prediscosphaera cretacea cretacea
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	●	●?	*P. cretacea lata
-	-	-	●	●	-	●	-	-	●	●	●	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	*P. cretacea ponticula
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	●	-	●	-	*P. honjoi
-	-	●	-	●	●	●	-	-	-	●	●	-	-	●	●	●	-	●	●	●	-	●	●	-	-	●	-	●	-	●	-	P. spinosa
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	●	-	-	-	-	-	-	-	-	-	-	Rucinolithus hayi
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	●	-	-	-	S. fossilis
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	-	*S. stegnus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	*Similicoronilithus primus
●	-	●	●	-	●	●	●	-	●	-	-	●	●?	-	●	●	●	●	●	-	●	●	●	-	-	●	-	-	-	●	-	Stephanolithion laffittei
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	Tetralithus obscurus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	T. pyramidus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	T. quadratus
-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	●	-	-	●	-	-	-	-	-	●	-	●	-	*Vagalapilla aachena
-	-	-	-	-	-	●	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*V. compacta compacta
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-	●	●	-	-	-	●	●	-	●	-	●	-	-	-	●	●	●	●	-	-	●	-	●	-	●	●	-	●?	-	●?	-	V. elliptica
●	-	-	-	-	-	●	-	-	-	-	●	-	-	-	-	-	-	●	-	-	-	-	-	-	-	●	-	●?	-	●	-	V. imbricata imbricata
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●	-	-	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	-	●	●	W. barnesae
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	*W. biporta
-	-	-	-	-	-	-	-	-	-	●	●	-	-	-	●	-	-	-	-	-	-	-	-	-	-	●	-	-	-	●	-	W. coronata
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*W. mastersii
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-	-	-	-	-	-	●	-	-	-	●	●	-	-	-	-	●	-	-	-	-	●	●	●	-	-	-	-	-	-	-	-	*W. ovata
-	-	-	-	-	●	●	●	-	●	-	-	-	-	-	●	-	●	●	●	-	●	●	●	-	●	●	-	-	-	-	-	W. paenepelagica
●	-	●	●	-	-	●	●	●	●	●	●	-	-	-	●	●	-	●	●	-	●	-	-	●	●	●	-	●	●	●	-	W.? parvidentata
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	*W. porta
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-	-	-	-	-	-	●	-	-	-	-	●	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	*W. quadriradiata
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	*W. virginica
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	-	-	-	-	-	-	-	-	-	-	-	*Z. biclavatus
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-	-	●	-	-	●	●	-	-	●	●	●	●	-	-	●	●	-	●	-	-	-	●	-	-	●	●	-	●	-	●	-	*Z. compactus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	●?	-	-	●	-	●	-	-	-	●	-	*Z. deflandrei
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-	-	-	●	-	-	●	-	-	-	●	●	-	-	-	-	-	-	-	-	-	●	●	-	-	-	-	-	-	-	●	-	Z. lacunatus
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-	-	-	●	-	-	●	-	-	●	-	●	●	-	-	-	-	●	●	●	-	-	●	●	-	-	-	-	-	-	-	-	Z.? phacelosus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	●	-	-	-	Z. sp. aff. Z. sigmoides
-	-	●	●	-	-	●	●	-	-	-	●	●	-	-	-	●	-	●	-	-	-	-	-	-	-	●	-	-	-	-	-	Z. sisyphus
●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	●	-	-	-	●	●	●	-	●	●	-	●	-	-	-	*Z. slaughteri
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coccolith floras have become known in equal detail. Within the Austin Chalk, new species appear not all together at one or a few horizons, but essentially at random. The samples show an occurrence of 1 to 11 new species in each 5- to 10-foot interval. The lower Santonian as a whole contains 52 species not known from the underlying Turonian-Coniacian, and thus appears to be well distinguished. Similar differences exist between Santonian and Campanian samples. Campanian floras are characterized by an abundance of species having distinctly perforated central areas—a character which can be seen in the light microscope.

A number of morphological gradients in related forms were noted to be stratigraphically ordered. *Vagalapilla*

TABLE 2. *Distribution of Coccolith Species Arranged in Order of First Appearances from Albian (ALB) to Maastrichtian (KG-11).*

		CONI		SANTONIAN																					CAMPANIAN						
LOCALITIES and SAMPLES in stratigraphic sequence from Albian (ALB) to Maastrichtian (KG-11)	ALB	C-4	N-0	S-1	S-2	Q-6	S-3	S-4	S-6	PSA	S-10	S-11	PS-1	SF-11	SF-10	N-100	PT-6	PH-8	WR	42a	42g	PB-50	LW-1	LW-2	N-11+8	LW-3	LW-4	B-15	B-22	F-14	B-8	KG-11
Cyclagelosphaera margereli	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-
Biscutum blacki	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	○	●	-	-	-	-	-
Cretarhabdus conicus	●	-	-	-	-	-	-	○	-	-	-	○	○	-	-	○	-	-	-	○	-	○	-	-	-	-	●	-	-	-	-	-
Zygodiscus elegans	●	○	-	-	-	○	-	○	-	-	-	○	-	-	-	○	-	-	-	○	-	○	○	-	-	-	○	-	●	-	-	-
*Z. slaughteri	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	○	-	○	-	-	-	○	○	○	-	○	○	-	●	-	-	-
Apertapetra gronosa	●	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	○	-	-	-	-	○	-	-	○	○	-	-	-	●	-
*Bidiscus rotatorius	●	-	-	○	-	-	○	○	-	-	○	-	-	○	○	○	○	-	○	○	-	-	○	○	-	-	○	-	○	○	●	-
Corollithion signum	●	-	-	○	○	-	○	○	-	○	○	○	-	-	-	○	○	○	○	○	-	○	○	○	○	○	○	-	-	-	●	-
Cretarhabdus schizobrachiatus	●	-	-	○	-	-	-	○	-	-	-	-	-	-	-	-	○	-	-	○	-	-	-	-	-	○	○	-	-	-	●	-
Lithraphidites carniolensis	●	○	-	○	-	-	○	○	-	○	-	○	○	-	-	○	○	○	○	-	-	-	○	○	-	○	○	-	○	-	●	-
Parhabdolithus granulatus	●	-	-	○	-	-	-	○	-	○	○	○	○	-	-	○	○	○	-	○	-	○	○	○	-	-	○	-	-	○	●	-
Stephanolithion laffittei	●	-	○	○	-	○	○	○	-	○	-	-	○	○?	-	○	○	○	○	○	-	○	○	○	-	-	○	-	-	-	●	-
Vagalapilla imbricata imbricata	●	-	-	-	-	-	○	-	-	-	-	○	-	-	-	-	-	-	○	-	-	-	-	-	-	-	○	-	○?	-	●	-
Watznaueria ? parvidentata	●	-	○	○	-	-	○	○	○	○	○	○	-	-	-	○	○	-	○	○	-	○	-	-	○	○	○	-	○	○	●	-
Cretarhabdus crenulatus crenulatus	●	○	○	○	○	○	○	○	○	○	○	○	○	○	-	○	○	○	○	○	○	○	○	○	-	○	○	-	○	○	○	●
Watznaueria barnesae	●	-	-	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	-	○	●
Gartnerago concavum		●	-	○	-	○	○	○	○	○	○	○	○	-	-	○	○	○	○	○	○	○	○	○	-	-	○	-	○	-	●	-
*Vagalapilla elliptica		●	○	-	-	-	○	○	-	○	-	○	-	-	-	○	○	○	○	-	-	○	-	○	-	○	○	-	○?	-	●?	-
*Biscutum multiforme		●	-	-	-	-	-	-	-	-	-	-	-	○	-	○	-	-	-	○	-	-	-	○	-	-	-	-	-	○	○	●
Prediscosphaera cretacea cretacea		●	-	○	-	○	○	○	-	○	○	○	○	○	-	○	○	○	○	○	○	○	○	○	○	○	○	-	○	○	○	●
*Costacentrum lowei			●	-	-	-	-	-	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-
Lithastrinus grilli			●	-	-	-	-	○	-	-	○	-	○	-	-	○	-	-	○	-	-	-	-	-	-	○	●	-	-	-	-	-
Zygodiscus sisyphus			●	○	-	-	○	○	-	-	-	○	○	-	-	-	○	-	○	-	-	-	-	-	-	-	●	-	-	-	-	-
Parhabdolithus angustus			●	○	-	○	○	○	○	○	-	○	○	-	-	○	○	○	-	○	-	○	-	○	-	-	○	-	○	●	-	-
Chiastozygus amphipons			●	○	-	-	○	○	-	○	-	-	-	-	-	○	○	○	○	○	-	○	○	-	-	○	○	-	○	-	●	-
Microrhabdulus belgicus			●	○	-	-	○	○	-	○	○	-	○	○	-	○	○	○	○	○	○	○	-	○	-	○	○	-	-	-	●	-
Prediscosphaera spinosa			●	-	○	○	○	-	-	-	○	○	-	-	○	○	○	-	○	○	○	-	○	○	○	○	○	-	○	-	●	-
*Zygodiscus compactus			●	-	-	○	○	-	-	○	○	○	○	-	○	○	○	-	○	-	-	-	○	-	-	○	○	-	○	-	●	-
Cribrosphaera ehrenbergi			●	○	-	-	○	○	○	○	○	○	○	○	○	○	-	○	○	○	○	○	○	○	-	○	○	-	○	-	○	●
Micula decussata decussata			●	-	-	-	-	○	-	○	-	○	-	-	-	○	○	-	○	-	-	-	-	-	-	○	○	-	-	-	○	●
Pontilithus obliquicancellatus				●	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
*Watznaueria oblonga				●	-	-	○	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
*Cyclagelosphaera? chronolitha				●	-	○	○	-	-	-	-	○	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
*Vagalapilla imbricata elongata				●	-	-	-	-	-	○	-	-	-	-	-	○	-	-	○	-	●	-	-	-	-	-	-	-	-	-	-	-
*Chiastozygus bifarius				●	○	○	-	○	-	○	-	○	-	-	-	○	-	-	○	○	-	-	○	-	-	-	-	-	-	-	-	-
*Prediscosphaera imbricata ponticula				●	-	-	○	-	-	○	○	○	-	-	-	-	-	-	-	-	-	○	-	●	-	-	-	-	-	-	-	-
*Broinsonia bevieri				●	-	○	○	○	○	○	○	○	○	-	-	○	○	○	○	○	-	○	○	●	-	-	-	-	-	-	-	-
*Biscutum asymmetricum				●	-	○	○	-	-	○	-	-	-	-	-	-	○	○	○	-	-	-	○	●	-	-	-	-	-	-	-	-
Zygodiscus? phacelosus				●	-	-	○	-	-	○	-	○	○	-	-	-	-	○	○	-	-	-	○	●	-	-	-	-	-	-	-	-
*Cylindralithus asymmetricus				●	-	-	○	-	○	-	○	○	-	-	-	○	-	-	-	-	○	-	○	-	-	-	●	-	-	-	-	-
Costacentrum horticum				●	○	-	○	○	○	○	-	-	○	-	-	-	-	-	○	○	-	-	-	-	-	-	●	-	-	-	-	-
*Cylindralithus coronatus				●	-	-	-	○	-	○	○	○	○	-	-	-	-	○	○	-	-	-	-	-	-	-	●	-	-	-	-	-
Podorhabdus granulatus				●	○	-	○	-	-	-	-	-	-	-	-	-	-	-	○	-	-	○	-	-	-	-	●	-	-	-	-	-
Biscutum testudinarium				●	○	○	○	-	-	-	○	○	-	○	-	-	○	○	○	○	-	○	○	-	○	○	○	○	○	-	●	-
Corollithion exiguum				●	-	○	○	○	-	○	○	○	-	-	-	○	-	-	○	○	-	-	-	-	-	-	○	-	○	-	●	-
C. rhombicum				●	-	○	-	○	-	○	-	-	-	-	-	○	-	○	○	-	○	-	-	-	-	-	○	-	○	-	●	-
*Eiffellithus augustus				●	○	○	○	○	-	○	-	○	○	○	○	○	○	○	○	○	○	○	○	○	-	○	○	-	-	-	●	-
Lithastrinus floralis				●	-	-	○	○	-	○	-	-	○	-	-	-	○	○	-	-	-	○	-	-	-	-	-	-	-	-	●?	-
Zygodiscus lacunatus				●	-	-	○	-	-	-	○	○	-	-	-	-	-	-	-	-	-	○	○	-	-	-	-	-	-	-	●	-
Chiastozygus inturratus				●	-	-	○	○	-	-	○	○	-	○	○	○	○	-	○	○	○	○	○	○	-	-	-	-	○	-	○	●
Cribrosphaera laughtoni				●	○	-	○	○	○	○	○	○	-	○	○	○	○	○	○	○	○	-	○	○	-	-	-	-	○	-	○	●
Eiffellithus turriseiffeli				●	○	○	○	○	-	○	-	○	○	○	-	○	○	-	○	○	○	○	○	○	-	-	○	-	○	○	○	●
Cretarhabdus unicornis					●	○	○	-	-	-	-	○	-	○	-	-	-	-	-	-	-	-	-	●?	-	-	-	-	-	-	-	-
*Zygodiscus minimus						●	○	○	-	○	-	○	○	○	○	-	○	-	○	○	-	○	○	●	-	-	-	-	-	-	-	-
*Chiastozygus propagulis						●	-	-	-	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-

[First and last occurrences indicated by black circles, intermediate ones by open circles.]

compacta compacta BUKRY, n. sp., from lower Santonian samples has a somewhat irregular central area and a serrate margin. *Vagalapilla compacta integra* BUKRY, n. ssp., from the lower Campanian has a well-ordered central area and a smooth margin. This tendency toward better ordering of elements and reduction of serrate outlines was noted in a number of forms, e.g., *Pontilithus obliquicancellatus* GARTNER to *Pontilithus complexus* BUKRY, n. sp., and in *Corollithion rhombicum* (STRADNER & ADAMIKER). The size of the cross in *Bidiscus cruciatus cruciatus*

TABLE 2. *(Continued.)*

SANTONIAN																				CAMPANIAN							
Q-6	S-3	S-4	S-6	PSA	S-10	S-11	PS-1	SF-11	SF-10	N-100	PT-6	PH-8	WR	42a	42g	PB-50	LW-1	LW-2	N-11+8	LW-3	LW-4	B-15	B-22	F-14	B-8	KG-11	LOCALITIES and SAMPLES in stratigraphic sequence from Albian (ALB) to Maastrichtian (KG-11)
•	o	o	-	o	-	-	-	-	-	o	o	o	o	o	-	o	o	o	-	o	•	-	-	-	-	-	Watznaueria paenepelagica
•	-	-	-	-	o	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	Zygodiscus theta
•	o	o	-	o	-	o	o	o	-	o	o	o	o	o	o	o	o	o	-	o	o	-	o	o	•	-	Vagalapilla octoradiata
	•	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*V. compacta compacta
	•	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*Marthasterites furcatus simplex
	•	-	-	-	-	o	-	-	-	-	o	-	o	•	-	-	-	-	-	-	-	-	-	-	-	-	*Chiastozygus planus
	•	-	-	-	-	o	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	*Watznaueria quadriradiata
	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	*Rucinolithus sumastrocyclus
	•	-	-	-	o	o	-	-	-	-	o	-	-	-	-	o	o	•	-	-	-	-	-	-	-	-	*Watznaueria ovata
	•	-	-	-	o	o	-	-	-	o	-	-	-	o	-	-	-	-	-	o	•	-	-	-	-	-	Chiastozygus plicatus
	•	o	-	o	-	-	-	-	-	o	-	-	o	o	-	o	-	-	-	o	•	-	-	-	-	-	*Podorhabdus quadriperforatus
	•	-	-	-	o	-	-	o	-	-	-	-	o	o	-	o	o	o	-	-	o	-	-	-	•	-	*Amphizygus brooksii brooksii
	•	-	-	-	-	-	-	-	-	o	o	-	-	-	-	-	o	-	-	-	-	-	-	-	•	-	*Cyclagelosphaera rotaclypeata
	•	o	o	-	-	-	-	-	-	o	-	o	o	-	-	o	-	-	-	o	o	-	-	-	•	-	Podorhabdus dietzmanni
		•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	Zygodiscus acanthus
			•	-	-	o	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-	*Broinsonia furtiva
				•	-	o	o	-	-	-	o	o	o	o	o	o	-	o	-	-	o	-	o	-	•	-	*Parhabdolithus fischeri
					•	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Kamptnerius punctatus
					•	o	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	Gartnerago costatum costatum
					•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*Broinsonia ? orthocancellata
					•	o	-	-	-	-	-	-	-	-	-	-	-	-	-	o	•	-	-	-	-	-	Marthasterites furcatus furcatus
					•	-	-	-	-	o	-	-	o	-	-	-	-	-	-	-	•	-	-	-	-	-	Micula decussata concava
					•	-	-	-	-	-	o	-	-	-	o	-	-	-	-	-	o	o	•	-	-	-	Lucianorhabdus cayeuxi
					•	o	-	o	-	-	-	-	o	o	-	-	-	o	-	o	-	-	-	-	•	-	Braarudosphaera bigelowi bigelowi
					•	o	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	Kamptnerius magnificus magnificus
					•	-	-	-	-	-	-	-	-	o	-	-	o	-	-	-	-	-	o	-	•	-	*Vagalapilla aachena
					•	o	-	-	-	o	-	-	-	-	-	-	-	-	-	-	o	-	-	-	•	-	Watznaueria coronata
					•	o	o	-	-	o	-	o	o	o	-	o	-	o	-	o	o	-	o	-	•	-	Zygodiscus fibuliformis
						•	-	-	-	-	o	-	-	-	-	o	-	-	-	-	•	-	-	-	-	-	*Chiastozygus interruptus
						•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*Cylindralithus nudus
						•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	*Amphizygus brooksii nanus
						•	o	o	-	o	-	-	o	o	-	o	o	o	-	o	•	-	o	o	•	-	*Bidiscus cruciatus cruciatus
								•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*Nannoconus farinaccae
								•	o	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	-	*Amphizygus minimus
										•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*Bidiscus monocavus
										•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Marthasterites jucundus
										•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*Watznaueria mastersii
										•	-	-	-	-	-	-	-	-	-	-	-	-	o	-	•	-	*Prediscosphaera honjoi
										•	-	-	-	-	-	o?	-	-	o	-	o	-	-	-	•	-	*Zygodiscus deflandrei
												•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*Podorhabdus reinhardtii
												•	-	-	-	•	-	-	-	-	-	-	-	-	-	-	Rucinolithus hayi
												•	o	-	-	-	-	-	-	o	o	-	•	-	-	-	*Bidiscus cruciatus multicruciatus
													•	-	-	-	-	-	-	-	-	-	-	-	-	-	*Hexangulolithus primus
													•	-	-	-	-	-	-	-	-	-	-	-	-	-	*Scapholithus stegnus
													•?	•	-	-	-	-	-	-	-	-	-	-	-	-	*Hexalithus gardetae
													•	-	-	o	-	-	-	•	-	-	-	-	-	-	Zygodiscus biperforatus
													•	-	-	-	-	-	-	-	•	-	-	-	-	-	*Cylindralithus biarcus
														•	•	-	-	-	-	-	-	-	-	-	-	-	*Zygodiscus biclavatus
														•	-	-	-	-	-	o	•	-	-	-	-	-	*Chiastozygus synquadriperforatus
														•	-	-	-	-	-	-	-	o	-	•	-	-	C. disgregatus
															•	-	-	o	-	-	-	-	-	-	•	-	*Braarudosphaera bigelowi imbricata
																	•	-	-	-	-	-	-	-	-	-	Tetralithus quadratus
																		•	-	o	o	-	•	-	-	-	Watznaueria martelae
																		•	-	o	-	-	-	-	•	-	*Amphizygus papillatus
																		•	-	-	-	-	-	-	•	-	Braarudosphaera africana

BUKRY, n. sp., becomes larger in younger samples. Conversely, within a single sample a number of morphologically related variations may occur within a genus or species. The *Cribrosphaera ehrenbergi* ARKHANGELSKY and *Broinsonia parca* (STRADNER) specimens from sample LW-4 show a continuous range from fewer to more perforations.

Evolution of slight morphologic changes can be traced in some groups, whereas others have no known predecessors and seem to involve greater evolutionary jumps. As examples of the former case, *Gartnerago costatum costatum* (GARTNER) from the Santonian has perforations with a single crossbar in them; however, by early Campanian, a new subspecies, *G. costatum porolatum* BUKRY, n. ssp.

TABLE 2. *(Continued.)*

CAMPANIAN							
LW-3	LW-4	B-15	B-22	F-14	B-8	KG-11	LOCALITIES and SAMPLES in stratigraphic sequence from upper Santonian (LW-2) to Maastrichtian (KG-11)
●	●	-	-	-	-	-	*Broinsonia dentata
●	●	-	-	-	-	-	*B. handfieldii
●	●	-	-	-	-	-	B. parca
●	●	-	-	-	-	-	*Discoaster ? hayi
●	●	-	-	-	-	-	Marthasterites furcatus crassus
●	●	-	-	-	-	-	*Vagalapilla dorfii
●	●	-	-	-	-	-	*Zygodiscus macleodae
●	○	-	-	-	●	-	*Cretarhabdus multicavus
	●	-	-	-	-	-	Anoplosolenia brasiliensis
	●	-	-	-	-	-	*Arkhangelskiella specillata ethmopora
	●	-	-	-	-	-	*Broinsonia ? ethmoquadrata
	●	-	-	-	-	-	*B. staytonae
	●	-	-	-	-	-	*Chiastozygus garrisonii
	●	-	-	-	-	-	*Corollithion ellipticum
	●	-	-	-	-	-	*Cretarhabdus crenulatus hansmanii
	●	-	-	-	-	-	*C. loriei
	●	-	-	-	-	-	Cribrosphaera pelta
	●	-	-	-	-	-	*Cyclagelosphaera baticlypeata
	●	-	-	-	-	-	*C. specioclypeata
	●	-	-	-	-	-	*Cyclococcolithus? waxahachia
	●	-	-	-	-	-	*Cylindralithus sculptus
	●	-	-	-	-	-	C. serratus
	●	-	-	-	-	-	*Discoaster ? noelae
	●	-	-	-	-	-	*Discolithina ? porosuturalis
	●	-	-	-	-	-	*Gartnerago costatum porolatum
	●	-	-	-	-	-	*G. zipperum
	●	-	-	-	-	-	*Heteromarginatus wallacei
	●	-	-	-	-	-	*Kamptnerius percivalii
	●	-	-	-	-	-	Parhabdolithus regularis
	●	-	-	-	-	-	*Percivalia pontilitha
	●	-	-	-	-	-	*P. porosa
	●	-	-	-	-	-	*Pontilithus complexus
	●	-	-	-	-	-	*Scapholithus dubius
	●	-	-	-	-	-	*Vagalapilla dentata dentata
	●	-	-	-	-	-	*V. dentata aperta
	●	-	-	-	-	-	Watznaueria actinosa
	●	-	-	-	-	-	*W. biporta
	●	-	-	-	-	-	*W. porta
	●	-	-	-	-	-	*W. virginica
	●	-	●	-	-	-	Scapholithus fossilis
	●	-	●	-	-	-	Zygodiscus sp. aff. Z. sigmoides
	●	-	○	-	●	-	*Ethmorhabdus camaratus
		●	-	-	-	-	*Gartnerago sp.
		●	○	-	○	●	*Kamptnerius magnificus sculptus
			●	-	-	-	*Discolithina? furlongii
			●	-	-	-	*D.? hallii
			●	-	-	-	*D.? pagei
			●	-	-	-	D.? polygonata
			●	-	●	-	*Angulofenestrellithus snyderi
			●	-	●	-	*Prediscosphaera germanica
			●	-	●	-	*Watznaueria prolongata
			●	-	●	-	*Zygodiscus meudini
			●	-	○	●?	*Prediscosphaera cretacea lata
					●	-	Braarudosphaera sp. aff. B. discula
					●	-	*Similicoronilithus primus
					●	-	Tetralithus obscurus
					●	-	T. pyramidus
					●	-	*Vagalapilla compacta integra
					●	●	Arkhangekskiella cymbiformis
						●	*Lithraphidites grossopectinatus
						●	Nephrolithus gorkae
						●	*Zygodiscus? megamarginatus

was dominant. This form has larger perforations that are always spanned by two or three crossbars. Within the Santonian, the appearance of the simply crossed form *Bidiscus cruciatus cruciatus* BUKRY, n. ssp., was shortly followed by the appearance of *B. cruciatus multicruciatus* BUKRY, n. ssp., which has a slightly more complex cross structure. Other examples of gradual morphological evolution can be observed in the closing of the four central-area openings of *Vagalapilla elliptica* (GARTNER) during the Santonian-Campanian interval, also in the systematic closing of the small angle of the rhombohedral frame of *Corollithion rhombicum* (STRADNER & ADAMIKER) from an average angle of 67° in Santonian to 51° in Campanian. *Cretarhabdus crenulatus crenulatus* BRAMLETTE & MARTINI, as one of the important elements in most Upper Cretaceous floras, was a conservative line, but in the early Campanian a subspecies with central-area spanning bars set distinctly apart and having fine ornamentation on the bars appeared. Such slight modifications can be easily traced to a predecessor.

Some morphologic changes, however, do involve evolutionary jumps. For example, *Cribrosphaera pelta* (GARTNER), which has rim and central-area ultrastructure like *Cribrosphaera ehrenbergi* ARKHANGELSKY, has three complete rims instead of the two rims observed in all other similarly constructed species. There are no intermediate forms. Species such as *Ethmorhabdus camaratus* BUKRY, n. sp., *Discolithina? pagei* BUKRY, n. sp., D? *porosuturalis* BUKRY, n. sp., and *Discoaster? hayi* BUKRY, n. sp., appear abruptly with no recognizable closely related ancestors.

CORRELATION AND ZONATION

In correlating reference samples to the Texas sections it was observed that the reference sample from the base of the Pierre Shale in Knox County, Nebraska, contains species characteristic of the Texan Santonian and none characteristic of the lower Campanian of Texas. The 1952 COBBAN & REESIDE correlation charts indicate a Campanian (Taylor) equivalence for this horizon. Though the coccolith flora is sparse, a Santonian (Austin) correlation is more likely. PESSAGNO's (1966) assignment of the lower Austin Chalk at Austin to the Coniacian and the lower Austin Chalk at Dallas to the Santonian is supported by the distribution of the *Marthasterites furcatus* (DEFLANDRE) complex. These nannofossils are common in the lower chalk at Dallas but are not present in the lower chalk at Austin. Albian and Maastrichtian reference samples, given brief attention, demonstrate long ranges of some Upper Cretaceous forms, e.g., *Cretarhabdus crenulatus crenulatus* BRAMLETTE & MARTINI, *Cribrosphaera ehrenbergi* ARKHANGELSKY, and *Watznaueria barnesae* (BLACK). Reference samples from the Santonian of Europe, SF-11 and SF-10, show assemblages correlative to the Austin Chalk of Texas.

Amphizygus minimus BUKRY, n. gen., n. sp., appears in the Santonian of France and occurs in sample LW-1 from the Austin Chalk. In addition, four other new species appear in the lower Austin Chalk and also occur in the sparse Santonian assemblage from France: *Amphizygus brooksii brooksii* Bukry, n. gen., n. sp., *Bidiscus cruciatus cruciatus* Bukry, n. gen., n. sp., *Eiffellithus augustus* Bukry, n. sp.; and *Zygodiscus minimus* Bukry, n. sp. A minor variety of *Watznaueria barnesae* (Black) with several bulbous proximal shield elements appears first in SF-11 and sample 42a from the upper Austin Chalk at Austin. Campanian samples from Europe and Texas which show a total of 51 species first reported from the Campanian, contain only three first-occurring species in common: *Cretarhabdus multicavus* Bukry, n. sp., *Ethmorhabdus camaratus* Bukry, n. sp., and *Zygodiscus* sp. aff. *Z. sigmoides* Bramlette & Sullivan. Therefore, even though extensive sections were not sampled, it is apparent that at least two distinct coccolith assemblages are present in the Campanian. The floras of the numerous Santonian samples studied also indicate that two assemblages are present there.

These four assemblages are defined as new coccolith assemblage zones for the Upper Cretaceous. In the Santonian, the *Amphizygus minimus* Zone succeeds the *Cyclagelosphaera? chronolitha* Zone. In the Campanian the *Prediscosphaera germanica* Zone succeeds the *Zygodiscus macleodae* Zone.

CYCLAGELOSPHAERA? CHRONOLITHA ZONE

First occurring within this Zone are: *Amphizygus brooksii brooksii* Bukry, n. sp., *Chiastozygus planus* Bukry, n. sp., *C. plicatus* Gartner, *Cylindralithus asymmetricus* Bukry, n. sp., *Cylindralithus coronatus* Bukry, n. sp., *Podorhabdus quadriperforatus* Bukry, n. sp., and *Zygodiscus lacunatus* Gartner. The top of this lower Santonian interval is marked by the last occurrences of *Cyclagelosphaera? chronolitha* Bukry, n. sp., *Kamptnerius punctatus* Stradner, *Vagalapilla compacta* Bukry, n. sp., and by the first occurrences of *Bidiscus cruciatus cruciatus* Bukry, n. sp., and *Parhabdolithus fischeri* Bukry, n. sp., Other common species that help to identify this interval are: *Bidiscus rotatorius* Bukry, n. sp., *Biscutum testudinarium* Black, *Broinsonia bevieri* Bukry, n. sp., *Chiastozygus bifarius* Bukry, n. sp., *Costacentrum horticum* (Stradner, Adamiker & Maresch), *Gartnerago concavum* (Gartner), *Lithastrinus floralis* Stradner, *Parhabdolithus angustus* (Stradner), *Prediscosphaera cretacea ponticula* Bukry, n. ssp., *Zygodiscus compactus* Bukry, n. sp., and *Zygodiscus sisyphus* Gartner. Long-ranging Upper Cretaceous forms such as *Effellithus turriseifleli* (Deflandre) and *Watznaueria barnesae* (Black) are abundant. There are good reference localities at Dallas, Texas (S, PS, and PT), in the lower Austin Chalk.

AMPHIZYGUS MINIMUS ZONE

A number of characteristic species occur first within this zone: *Amphizygus minimus* Bukry, n. sp., *A. papillatus* Bukry, n. sp., *Bidiscus cruciatus multicruciatus* Bukry, n. ssp., *Chiastozygus synquadriperforatus* Bukry, n. sp., *Cylindralithus biarcus* Bukry, n. sp., *Zygodiscus biclavatus* Bukry, n. sp., and *Z. biperforatus* Gartner. This middle Santonian interval extends from the last occurrences of *Cyclagelosphaera? chronolitha* Bukry, n. sp., *Kamptnerius punctatus* Stradner, and *Vagalapilla compacta compacta* Bukry, n. sp., to the last occurrence of *Biscutum asymmetricum* Bukry, n. sp., *Broinsonia bevieri* Bukry, n. sp., *Chiastozygus bifarius* Bukry, n. sp., *Lithastrinus floralis* Stradner, *Watznaueria ovata* Bukry, n. sp., *Zygodiscus minimus* Bukry, n. sp., and *Z. phacelosus* (Stover). Other common species characterizing this interval are: *Amphizygus brooksii brooksii* Bukry, n. sp., *Bidiscus cruciatus cruciatus* Bukry, n. sp., (small-crossed forms), *Biscutum testudinarium* Black, *Braarudosphaera bigelowi bigelowi* (Gran & Braarud), *Chiastozygus inturratus* (Reinhardt), *Corollithion signum* Stradner, *Gartnerago concavum* (Gartner), *Parhabdolithus fischeri* Bukry, n. sp., *Vagalapilla elliptica* (Gartner), *V. octoradiata* (Gorka), *Watznaueria paenepelagica* (Stover), and *Zygodiscus elegans* Gartner. The usual assemblage of long-ranging Upper Cretaceous species is also abundant.

This assemblage is readily distinguished from the *Zygodiscus macleodae* Zone by the absence of diagnostic Campanian forms such as: *Broinsonia dentata* Bukry, n. sp., *Cretarhabdus multicavus* Bukry, n. sp., *Ethmorhabdus camaratus* Bukry, n. sp., *Gartenerago costatum porolatum* Bukry, n. ssp., and others. Since an unconformity lies between the samples here referred to the lower Campanian *Zygodiscus macleodae* Zone and to the middle Santonian *Amphizygus minimus* Zone, an intermediate zone is possible. There are good reference localities in the middle and upper Austin Chalk of Texas at Dallas (PB, WR, PH, PT), Austin ("42"), and Lake Waxahachie (LW). In Europe, the type middle Santonian at Saintes, France (SF) serves as reference for this interval.

ZYGODISCUS MACLEODAE ZONE

This lower Campanian interval is characterized by the first occurrences and presence of *Zygodiscus macleodae* Bukry, n. sp., *Arkhangelskiella specillata ethmopora,* Bukry, n. ssp., *Broinsonia handfieldii* Bukry, n. sp., *Cretarhabdus crenulatus hansmanii* Bukry, n. ssp., *C. multicavus* Bukry, n. sp., *Cribrosphaera pelta* (Gartner), *Discoaster? hayi* Bukry, n. sp., *Ethmorhabdus camaratus* Bukry, n. sp., *Gartnerago costatum porolatum* Bukry, n. ssp., *Parhabdolithus regularis* (Gorka), *Percivalia pontilitha* Bukry, n. sp., *P. porosa* Bukry, n. sp., *Vagalapilla dentata dentata* Bukry, n. sp., *V. dentata aperta* Bukry, n. ssp., *V. dorfii* Bukry, n. sp. Other associated common species are: *Broinsonia parca* (Stradner), *Corollithion rhombicum* (Stradner & Adamiker), *Costacentrum horticum* (Stradner, Adamiker & Maresch), *Chiastozygus plicatus* Gartner, *C. slaughteri* Bukry, n. sp., *S. synquadriperforatus* Bukry, n. sp., *Cretarhabdus conicus* Bramlette & Martini, *Cribrosphaera ehrenbergi* Ark-

HANGELSKY, *Cylindralithus asymmetricus* BUKRY, n. sp., *Lithastrinus grilli* STRADNER, *Marthasterites furcatus furcatus* (DEFLANDRE), *Micula decussata decussata* VEKSHINA, *Podorhabdus quadriperforatus* BUKRY, n. sp., *Watznaueria paenepelagica* (STOVER), and *Zygodiscus deflandrei* BUKRY, n. sp. The usual assemblage of long-ranging Upper Cretaceous species is also abundant.

Many species that characterize the Santonian zones do not occur in the *Zygodiscus macleodae* Zone. Some of these restricted forms are: *Biscutum asymmetricum* BUKRY, n. sp., *Broinsonia bevieri* BUKRY, n. sp., *Chiastozygus bifarius* BUKRY, n. sp., *C. planus* BUKRY, n. sp., *Lithastrinus floralis* (STRADNER), *Prediscosphaera cretacea ponticula* BUKRY, n. ssp., *Watznaueria ovata* BUKRY, n. sp., *W. quadriradiata* BUKRY, n. sp., *Zygodiscus minimus* BUKRY, n. sp., *Z? phacelosus* (STOVER). The reference locality for this zone is the lower Taylor Marl at Lake Waxahachie, Texas (LW-3,-4).

PREDISCOSPHAERA GERMANICA ZONE

This interval is characterized by the first occurrences, at the base, of *Prediscosphaera germanica* BUKRY, n. sp., *Angulofenestrellithus snyderi* BUKRY, n. sp., *Kamptnerius magnificus sculptus* BUKRY, n. ssp., *Prediscosphaera cretacea lata* BUKRY, n. ssp., *P. honjoi* BUKRY, n. sp., *Vagalapilla compacta integra* BUKRY, n. ssp., and *Zygodiscus meudini* BUKRY, n. sp. Other common species are: *Amphizygus brooksii brooksii* BUKRY, n. sp., *Arkhangelskiella cymbiformis* VEKSHINA, *Bidiscus cruciatus cruciatus* BUKRY, n. sp., (large-crossed forms), *Biscutum multiforme* BUKRY, n. sp., *B. testudinarium* BLACK, *Chiastozygus disgregatus* (STOVER), *Corollithion rhombicum* (STRADNER & ADAMIKER), *Cretarhabdus conicus* BRAMLETTE & MARTINI, *C. multicavus* BUKRY, n. sp., *Cribrosphaera laughtoni* (BLACK), *Ethmorhabdus camaratus* BUKRY, n. sp., *Lucianorhabdus cayeuxi* DEFLANDRE, *Microrhabdulus belgicus* HAY & TOWE, *Vagalapilla octoradiata* (GORKA), and *Watznaueria? parvidentata* (DEFLANDRE). The common assemblage of long-ranging Upper Cretaceous forms such as *Eiffellithus turriseiffeli* (DEFLANDRE), *Prediscosphaera cretacea* (ARKHANGELSKY), and *Watznaueria barnesae* (BLACK) is also present.

Notably missing are many of the distinctive species that characterize the lower Campanian *Zygodiscus macleodae* Zone. Species such as: *Chiastozygus synquadriperforatus* BUKRY, n. sp., *Costacentrum horticum* (STRADNER, ADAMIKER & MARESCH), *Cribrosphaera pelta* (GARTNER) *Cylindralithus asymmetricus* BUKRY, n. sp., *Gartnerago costatum porolatum* BUKRY, n. ssp., *Lithastrinus grilli* STRADNER, *Marthasterites furcatus furcatus* (DEFLANDRE), *Vagalapilla dorfii*, BUKRY, n. sp., and *Zygodiscus macleodae* BUKRY, n. sp., are not present. In fact, the distinct contrast between the *Prediscosphaera germanica* Zone assemblage and that of the *Zygodiscus macleodae* Zone below suggests that there is an unstudied interval not represented in the samples from Texas and Europe. The diagnostic Maastrichtian species of *Lithraphidites* and *Nephrolithus* are not present in the *Prediscosphaera germanica* Zone. Reference localities for this zone are the Craie de Meudon at Paris, France (B-8), and the Aachen marl at Aachen, Germany (B-22).

DIFFERENCE IN ASPECT

One of the problems in working with coccoliths is that a given coccolith has distinct aspects for proximal and distal sides. In light microscopy, a specimen can be turned over if mounted in viscous medium. In electron microscopy, this is of course not possible, but if the preparation is a good one, curvature and thickness of the coccolith can be interpreted from the shadow; the carbon replica will reveal the trace of element sutures in the lower rims or underside of the upper rims. Once the distal structures of a genus are recognized, in a stemmed form for example, element counts and attitudes coupled with overall central-area pattern can be used to correlate proximal and distal views. In most double-rim forms the distal rim has the larger diameter. The distal surface of most coccoliths is also convex. Structure along coccolith planar axes usually shows a large number of elements in proximal view. Each genus or subfamily has special ultrastructures which differentiate proximal and distal views.

LIGHT VERSUS ELECTRON MICROSCOPY

A light microscope check of sample LW-4 (electron microscope flora=102 species) indicates that only larger members, approximately 50 percent of the assemblage, are optically identifiable. Determination of distal and proximal views of small forms is difficult, especially where there is no stem structure. Since definite identification of the small coccoliths of an assemblage cannot be done by light microscopy, light and electron microscope studies are not directly comparable. Studies of abundance done by light microscopy will tend to favor larger more readily identifiable forms. Of course, size bias can be a problem in electron microscopy too. In isolating the coccolith fraction from the original sample it is possible to eliminate the smaller (less than 4 μ) or larger (more than 12 μ) members of the assemblage.

SIZE-RANGE BETWEEN AND WITHIN SPECIES

Of the 94 new species described in this study 40 percent are less than 6 μ in diameter, 45 percent range from 6 to 10 μ, and 14 percent exceed 10 μ. The total range represented is 1.7 to 20 μ. Previous light-microscope studies have identified most of the larger taxa in this sequence. In general, the smallest representatives of a species or subspecies are about half the size of the largest. Because of this variation, and recent observations on *Crystallolithus hyalinus* GAARDER & MARKALI showing two sizes of the same structural scales on one individual, size is not given much taxonomic significance.

POLYMORPHISM

Work with recent coccolithophores has suggested that the coccoliths of the fossil record represent only one stage (nonmotile) of a two-stage life cycle. The skeletal plates of the motile stage are distinctive in being constructed of elements of uniform size and shape. The open, checker-patterned coccoliths of the motile stage are called holococcoliths; the coccoliths of the nonmotile stage are called heterococcoliths because the constituent elements are of various shapes and sizes. Holococcoliths have only been identified from living forms. Their apparent absence from the fossil record suggests that they become disaggregated upon death, contributing to the indeterminate minute calcite particles which make up an appreciable fraction of chalk (16 percent of some Texas chalks, as compared to 21 percent coccoliths, according to BRAMLETTE, 1958).

SUPRAGENERIC CLASSIFICATION

As one-celled photosynthetic algae, coccolith-producing organisms are generally classified according to botanical nomenclature (HAY, MOHLER, *et al.*, 1967). That system is followed here.

Outline of Coccolith Classification

Kingdom PLANTAE
Subkingdom PROTOBIONTA Rothmaler, 1948
Division PHAEOPHYTA Wettstein, emend. Rothmaler, 1949
Subdivision CHRYSOPHYTINA Rothmaler, 1949
Class COCCOLITHOPHYCEAE Rothmaler, 1949
Subclass COCCOLITHOPHYCIDAE Rothmaler, 1949
Order HELIOLITHAE Deflandre, 1952
Suborder COCCOLITHINEAE Kamptner, 1928
Family ARKHANGELSKIELLACEAE Bukry, new family
Subfamily ARKHANGELSKIELLOIDAE Gartner, 1968
Genus *Arkhangelskiella*
Broinsonia
Subfamily KAMPTNERIOIDEAE Bukry, new subfamily
Genus *Gartnerago*
Kamptnerius
Family COCCOLITHACEAE Kamptner, 1928
Genus *Apertapetra*
Bidiscus
Biscutum
Cyclagelosphaera
Cyclococcolithus?
Similicoronilithus
Watznaueria
Family RHABDOSPHAERACEAE Lemmermann, 1908
Genus *Cretarhabdus*
Ethmorhabdus
Podorhabus
Prediscosphaera
Family STEPHANOLITHIONACEAE Bukry, new family
Genus *Corollithion*
Cylindralithus
Lithastrinus
Stephanolithion
Family SYRACOSPHAERACEAE Lemmermann, 1908
Subfamily SYRACOSPHAEROIDEAE Kamptner, 1928
Genus *Costacentrum*
Cribrosphaera
Discolithina?
Nephrolithus
Subfamily ZYGODISCOIDEAE Bukry, new subfamily
Genus *Amphizygus*
Angulofenestrellithus
Chiastozygus
Eiffellithus
Heteromarginatus
Parhabdolithus
Percivalia
Pontilithus
Vagalapilla
Zygodiscus
Order BRAARUDOSPHAERALES Deflandre, 1947
Family BRAARUDOSPHAERACEAE Deflandre, 1947
Genus *Braarudosphaera*
Hexalithus
Hexangulolithus
Rucinolithus
Tetralithus
Family CALCIOSOLENACEAE Kamptner, 1937
Genus *Anoplosolenia*
Scapholithus
Family DISCOASTERACEAE Tan, 1927
Genus *Discoaster?*
Marthasterites
Family MICRORHABDULACEAE Deflandre, 1959
Genus *Microrhabdulus*
Incertae sedis
Genus *Lithraphidites*
Lucianorhabdus
Micula
Nannoconus

SYSTEMATIC PALEONTOLOGY

Family ARKHANGELSKIELLACEAE Gartner, 1965

[*nom. transl.* BUKRY, herein (*ex* Arkhangelskielloidae GARTNER, 1965)]

Large, elliptical coccoliths with complex rims built of two to four tiers, each rim tier composed of numerous elements. Large central areas divided into quadrants by axial or subaxial sutures that are outlined, usually, by marginal checker-arranged elements. No stem present. *U. Cret. (Coniac.-Maastricht.)*

Subfamily ARKHANGELSKIELLOIDEAE Gartner, 1965

Organ genus ARKHANGELSKIELLA Vekshina, 1959

ARKHANGELSKIELLA CYMBIFORMIS Vekshina

"Coccoliths of uncertain affinity," ARKHANGELSKY, 1912, v. 25, pl. 6, fig. 24.

Arkhangelskiella cymbiformis VEKSHINA, 1959, p. 66, pl. 2, fig. 3a-b.——STRADNER, 1963, p. 170, pl. 1, figs. 4. 4a-b.——BRAMLETTE & MARTINI, 1964, p. 297, pl. 1, figs. 3-9.——STOVER, 1966, p. 137, pl. 1, figs. 17-18, pl. 8, fig. 8 REINHARDT, 1965, p. 31, pl. 2, fig. 6.——REINHARDT, 1966, p. 31, pl. 6, fig. 1-3; pl. 22, fig. 14-19.——GARTNER, 1968, p. 38, pl. 1, figs. 1-6, pl. 4. fig. 1-4, pl. 6, fig. 1a-c.

Remarks.—Perforations may not completely pierce the central area. Each quadrant of the central area contains 1 to 5 regularly arranged perforations. Secondary sutures within the quadrants are not quite perpendicular to the subaxial sutures.

Size.—Maximum diameter, 8.6 μ.

Types.—Hypotypes, UI-H-3181 through UI-H-3183.

Occurrence.—Localities and samples, *B-8, KG-11.* Known range, Campanian-Maastrichtian.

Illustrations.—Plate 1, figures 1-3; 1, UI-H-3181, *KG-11,* distal, ×4320; 2, UI-H-3183, *B-8,* distal, ×6460; 3, UI-H-3182, *B-8,* proximal, ×6460.

ARKHANGELSKIELLA SPECILLATA ETHMOPORA Bukry n. ssp.

Description.—Processes that symmetrically divide perforations of the central area distinguish this subspecies, 3 to 6 processes meeting at center of each perforation to form sets of lesser perforations.

Maximum diameter.—13.0 μ.

Type.—Holotype, UI-H-3185 distal view (Pl. 1, fig. 6). Primary paratype, UI-H-3184 proximal view (Pl. 1, fig. 7). Other paratypes: UI-H-3184, UI-H-3186, UI-H-3187.

Occurrence.—Locality and sample, LW-4. Known range, Campanian.

Illustrations.—Plate 1, figures 4-7; 4, UI-H-3186, *LW-4,* distal, ×6140; 5, UI-H-3187, *LW-4,* proximal, ×5810; 6, holotype, UI-H-3185, *LW-4,* distal, ×5400; 7, UI-H-3184, *LW-4,* proximal, ×4660.

Organ genus BROINSONIA Bukry, n. gen.

Description.—Elliptical coccolith characterized by 2-cycle rim in distal view and 3-tier proximal rim, which is at 3 distinct levels with interelement sutures maintaining same inclination across each tier. Central area comprising single shield divided into quadrants by axial sutures, quadrants perforated in various manners.

Type species.—Broinsonia dentata BUKRY, n. sp.,

Remarks.—1) Distal plate elements are more orthogonal and more regularly arranged than those of *Gartnerago* BUKRY, n. gen. 2) The inner cycle of elements on the distal surface distinguishes *Broinsonia* from *Gartnerago* and *Arkhangelskiella* VEKSHINA. Only *Broinsonia* has a cycle of irregularly margined "square" elements which have a peripheral extension paralleling the outer margin of the cycle. These oddly shaped elements are usually further modified by having a broad dimple. 3) Perforations are slitlike or circular as in *Arkhangelskiella.* 4) The rims contain fewer elements than *Gartnerago.* 5) In proximal view, *Broinsonia* is not distinguished from *Arkhangelskiella* by rim structure. Central-area perforation or ornamentation is usually distinctive.

BROINSONIA BEVIERI Bukry, n. sp.

Description.—This is an elliptical form with an eccentricity of 1.3 to 1.4. Each rim of the 3 rim tiers is composed of 32 to 42 elements. The elements form approximately radial sutures and imbricate sinistrally slightly. In distal view, an inner cycle of elements appears to be irregularly constructed or preserved. In well-preserved material this cycle has distinctive alternating small and large *Broinsonia*-shaped elements as in other species of *Broinsonia.* The central-area structures are gradationally variable. All centers are based on the straight sutures aligned with ellipse axes. In one form a rounded cross is produced by a single row of a few elements on each side of the sutures. In another, an oval central area contains more elements. Although rim width varies, this central area retains a turtle-shell pattern.

Remarks.—The checkered pattern of the axial suture elements in proximal view and the complex rim tiers are common to Arkhangelskielloideae. The broad inner cycle on the distal surface serves to distinguish these forms as a *Broinsonia* species. The rim is composed of less regularly outlined elements than in other species of *Broinsonia.* In proximal view, sharp break is seen between the central area and inner cycle. No central-area perforations are present, as in other species of *Broinsonia.*

Size.—Maximum diameter, 7.8 μ.

Types.—Holotype, UI-H-3275, distal view (Pl. 1, fig. 8). Primary paratype, UI-H-3276, proximal view (Pl. 1, fig. 9). Other paratypes, UI-H-3268 through UI-H-3274, UI-H-3276, UI-H-3277.

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-1, LW-2, PB-50, N-100, PH-8, PS-1, PSA, PT-6, Q-2, Q-4, Q-6, S-1, S-3, S-4, S-6, S-10, S-11, WR, 42a.* Known range, Santonian.

Illustrations.—Plate 1, figures 8-12; holotype, UI-H-3275, *LW-1,* distal, ×6650. UI-H-3276, *LW-1,* proximal, ×7130. UI-H-3272, *PT-6,* distal, ×11,500. UI-H-3270, *S-4,* proximal, ×7130. UI-H-3269, *42a,* distal, ×11,000.

BROINSONIA DENTATA Bukry, n. sp.

Description.—The elliptical outline of this form has eccentricity of 1.2 to 1.7 (1.4 mean). The central area is divided by axial crossbars. Each quadrant has a large perforation, the outline of which is aligned with the axial and rim outlines. Individual processes arise from the axial margins of the perforations and extend into and across the opening toward the rim. The processes commonly do not meet the rim side. The typical number of processes in a perforation is 4 to 6. In distal view, there are 2 rim cycles, the inner one has distinctively shaped dimpled elements with a peripheral extension composed of 35 to 48 elements (42 mean). A small alternating set of elements, typical of *Broinsonia* species, does not extend to the inner margin of the cycle. This results in the outer margin of the cycle having twice as many elements as the inner margin. The outer rim cycle has 40 to 46 elements. Three rim tiers appear in proximal view.

Remarks.—In proximal view, the ellipse axes are lined by small alternating elements which produce a checkered pattern. This structure is found in most Arkhangelskielloideae.

Size.—Maximum diameter, 7.1 μ.

Types.—Holotype, UI-H-3278, distal view (Pl. 2, fig. 1). Primary paratype, UI-H-3282, proximal view (Pl. 2, fig. 2). Other paratypes, UI-H-3279 through UI-H-3283.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-3, LW-4.* Known range, Campanian.

Illustrations.—Plate 2, figures 1-3; 1, holotype, UI-H-3278, *LW-4,* distal, ×8750; 2, UI-H-3282, *LW-4,* proximal, ×10,100; 3, UI-H-3281, *LW-4,* distal, ×7300.

BROINSONIA? ETHMOQUADRATA Bukry, n. sp.

Description.—The eccentricity of this form is 1.3 to 1.5. The distal portion of its rim is largely indeterminate on the specimens available. Immediately adjacent to the recessed central area is a cycle of 3 layers with about 13 rod-elements in each layer. In proximal view, 3 separate rim tiers becoming larger distally can be observed. Outer rim cycle counts of 29 and 31 radial elements were made. A secondary cycle of 28 and 29 radial elements was also observed. The central area occupies 61 to 68 percent of the coccolith length. Axial crossbars with 2 rows of 3 to 5 elements divide the central area into quadrants. These are filled by a sievelike plate containing 16 to 24 small perforations arranged in staggered rows.

Remarks.—Comparison by complex rim and sievelike plate is made to *Broinsonia? staytonae* Bukry, n. sp. Distinction is based on equal-width crossbars, smaller size, central area proportion, and fewer sieve openings.

Size.—Maximum diameter, 4.7 μ.

Types.—Holotype, UI-H-3287, proximal view (Pl. 2, fig. 4). Primary paratype, UI-H-3286, distal view (Pl. 2, fig. 6). Other paratypes, UI-H-3284 through UI-H-3286.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4.* Known range, Campanian.

Illustrations.—Plate 2, figures 4-6; 4, holotype, UI-H-3287, *LW-4,* proximal, ×10,100; 5, UI-H-3285, *LW-4,* proximal, ×9030; 6, UI-H-3286, *LW-4,* distal, ×9500.

BROINSONIA FURTIVA Bukry, n. sp.

Description.—The elliptical outline of this form has an eccentricity of 1.5 to 1.6. Counts of 44, 38, and 35 inclined slightly clockwise and dextrally imbricate elements were observed in the outer rim cycle. The inner cycle, in distal view, shows the characteristic elements of *Broinsonia* with the outer margin containing about 40 elements and the inner margin about 20. The central area is composed of a narrow axial cross and 4 large, roughly triangular perforations in each quadrant. The perforations are largely closed by one thick longitudinal bar and several transverse bars. The secondary bars are recessed below the distal level of the central area.

Remarks.—The three specimens encountered are from the Austin Chalk. This form may give rise to *Broinsonia dentata* Bukry, n. sp. and *B.? orthocancellata* Bukry, n. sp., which also have bars filling the 4 central-area perforations.

Size.—Maximum diameter, 6.2 μ.

Types.—Holotype, UI-H-3289, distal view (Pl. 2, fig. 7). Paratypes, UI-H-3288, UI-H-3290.

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Peavy Avenue and Buckner Boulevard, Dallas, Texas. Localities and samples, *PB-50, S-6, S-11.* Known range, Santonian.

Illustrations.—Plate 2, figures 7-8; 7, holotype, UI-H-3289, *PB-50,* distal, ×8550; 8, UI-H-3290, *S-11,* distal, ×7600.

BROINSONIA HANDFIELDII Bukry, n. sp.

Description.—This elliptical coccolith has eccentricity of 1.4. The distinctive feature of the species is its large number of slender crossbars present in the 4 large perforations of the central-area quadrants. There are 6 to 8 crossbars paralleling the short subaxial suture and filling the elongate perforations. A few specimens have a short pair of crossbars paralleling the long axis, right at the short axis. The structure around the long axis tapers so as to be quite wide at the juncture with the short axis of the ellipse. The inner rim cycle in proximal view has 35 to 65 (43 mean) elements that incline slightly clockwise and imbricate sinistrally. In distal view, the distinctive *Broinsonia*-type inner cycle is composed of about 40 elements.

Remarks.—This form is distinguished from *Broinsonia? orthocancellata* Bukry, n. sp., by its inner crossbars and thick tapered, long-axis structure.

Size.—Maximum diameter, 9.6 μ.

Types.—Holotype, UI-H-3295, proximal view (Pl. 2, fig. 9). Primary paratype, UI-H-3291, distal view (Pl. 2, fig. 10). Other paratypes, UI-H-3291 through UI-H-3294.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-3, LW-4.* Known range, Campanian.

Illustrations.—Plate 2, figures 9-11; 9, holotype, UI-H-3295, *LW-4,* proximal, ×11,500; 10, UI-H-3291, *LW-3,* distal, ×8550; 11, UI-H-3293, *LW-4,* proximal, ×6650.

BROINSONIA? ORTHOCANCELLATA Bukry, n. sp.

Description.—This is an elliptical (eccentricity of 1.3 or 1.4) coccolith with checker-patterned subaxial suture structures. The central area has rows of slitlike perforations flanking the ellipse axes. The perforations are evenly spaced and aligned perpendicular to the axis which they border. Occurring in rows of 10 to 14 on either side of the long ellipse axis and 6 or 7 along the short axis, the perforations are similar to those in *Broinsonia handfieldii* Bukry, n. sp. The interperforation bars are thicker here, however. Only proximal views of this species are available. The inner rim cycle has 40 to 50 elements that imbricate sinistrally and incline little, if at all. The outer cycle has about 45 elements that incline slightly counterclockwise.

Remarks.—This form is distinguished from *Broinsonia handfieldii* Bukry, n. sp., by its prominent perforation rows perpendicular to the short axis, thicker interperforation bars, and lack of tapered long-axis crossbar.

Size.—Maximum diameter, 8.8 μ.

Types.—Holotype, UI-H-3301, proximal view (Pl. 2, fig. 12). Paratypes, UI-H-3297 through UI-H-3300.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and samples, *LW-4, S-10*. Known range, Campanian.

Illustrations.—Plate 2, figure 12; Plate 3, figures 1-2. Pl. 2, fig. 12, holotype, UI-H-3301, *LW-4*, proximal, ×6140.——Pl. 3, fig. 1-2; 1, UI-H-3300, *LW-4*, proximal, ×9440; 2, UI-H-3298, *S-10*, proximal, ×9440.

BROINSONIA PARCA (Stradner), Bukry, n. comb.

Arkhangelskiella parca Stradner, 1963, p. 176, pl. 1, fig. 3.——Bramlette & Martini, 1964, p. 298, pl. 1, fig. 1-2.——Gartner, 1968, p. 38, pl. 8, figs. 4-5, pl. 11, fig. 2a-c.

Arkhangelskiella magnacava Gartner, 1968, p. 38, pl. 18, fig. 24-25, pl. 22, fig. 9.

Remarks.—On the basis of a sample of more than 50 specimens, it is proposed that the definition of *Arkhangelskiella parca* be extended to include *A. magnacava* and several other previously undescribed forms. The distal rim structure of all of these forms corresponds to the distinctive *Broinsonia* type. The outer rim cycle has about 50 elements (42 to 56 observed). The characteristic inner cycle has about 50 elements at the outer margin of the cycle and about 25 at the inner margin.

A suite of perforate *Broinsonia* forms was encountered in a single lower Taylor Marl sample. Specimens with perforation counts of 2, 3, 4, 5, 6, 7, 8, 9, 18, 19, 37, 40+, 64, and 112 were encountered. Two members of this suite have been described. *Arkhangelskiella parca* was originally described as having "a few pores" and the holotype figure shows 12 perforations. *A. magnacava* was reported to have "large perforations" and the holotype figure shows a 6-perforation form.

The most common varieties have 4, 6, or 8 perforations. The occurrence of all of these forms with the same basic rim structure in the same sample indicates that they can presently be considered as a single species. Varieties might be designated according to perforation numbers (e.g., *Broinsonia parca* with 18).

A few specimens have crossbars in the perforations in the manner of *Gartnerago costatum porolatum* Bukry, n. ssp.

Size.—Maximum diameter, 11.5 μ.

Types.—Hypotypes, UI-H-3302 through UI-H-3309.

Occurrence.—Localities and samples, *LW-3, LW-4*. Known range, upper Turonian-upper Campanian.

Illustrations.—Plate 3, figures 3-10; 3, UI-H-3304, *LW-4*, distal, ×4550; 4, UI-H-3308, *LW-4*, proximal, ×4850; 5, UI-H-3306, *LW-4*, distal, ×7600; 6, UI-H-3305, *LW-4*, proximal, ×4900; 7, UI-H-3302, *LW-4*, distal, ×7000; 8, UI-H-3303, *LW-4*, distal, ×6650; 9, UI-H-3309, *LW-4*, distal, ×6140; 10, UI-H-3307, *LW-4*, proximal, ×8080.

BROINSONIA? STAYTONAE Bukry, n. sp.

Description.—The elliptical rim of this species has an eccentricity of 1.3 to 1.5. The rim is a complex of at least 3 tiers with 31 and 35 radial elements counted in the outer cycle. Distal rim structure is indeterminate. The central area occupies 67 to 77 percent of the coccolith length. In distal view, the central area has 2 subaxial crossbars with sievelike plates in the quadrants. The short crossbar has a median suture and is rotated 20° to 25° sinistrally from the short axis of the rim ellipse. Also in distal view, the 2 bars making the long crossbar are offset sinistrally from each other where they meet the short crossbar. The elements flanking the median sutures of these 2 long bars become distinctly wider from the rim to the center. The large quadrants resulting from this rim and crossbar structure are filled with a delicate sievelike plate which contains 20 to 40 perforations arranged in staggered rows. In proximal view, a secondary cycle of 34, 35, or 36 radial elements is observed. An inner rim cycle of 30 radial elements was noted in one specimen.

Remarks.—This form is attributed to *Broinsonia* Bukry, n. gen., on the basis of the wide variety of its central-area structures associated with a complex rim as found in this genus. *B. handfieldii* Bukry, n. sp., is the only form with a comparable inflated, long crossbar. The normal *Broinsonia* rim structure is not discernible. Aside from the closely related *B.? ethmoquadrata* Bukry, n. sp., the only other Cretaceous form with a sievelike plate structure is *Podorhabdus quadriperforatus* Bukry, n. sp.

Size.—Maximum diameter, 6.8 μ.

Types.—Holotype, UI-H-3310, distal view (Pl. 3, fig. 11). Primary paratype, UI-H-3311, proximal view (Pl. 3, fig. 12). Other paratypes, UI-H-3311 through UI-H-3314.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 3, figures 11-12; Plate 4, figure 1.——Pl. 3, fig. 11-12; 11, holotype, UI-H-3310, *LW-4*, distal, ×10,800; 12, UI-H-3311, *LW-4*, proximal, ×10,100.——Pl. 4, fig. 1, UI-H-3312, *LW-4*, proximal, ×9030.

Subfamily KAMPTNERIOIDEAE Bukry, n. subfam.

This group of large elliptical coccoliths has very complex rim structure. Of the three or four multi-element rim tiers, one is very broad. The central plate composed of a large number of elements can be perforate or closed. It is always convex distally. The subaxial to axial crossbar structures are prominent on the proximal surface and insignificant in distal view.

Organ genus GARTNERAGO Bukry, n. gen.

Description.—These elliptical forms are characterized by a set of 4 to 5 closely appressed rim tiers, of which 3 or 4 are visible proximally and the fourth or fifth distally. The central area is a single shield divided into quadrants by subaxial recessed sutures. The shield is convex distally and concave proximally. Alignment of one margin of polygonal elements of the central area forms the subaxial sutures. Single rows of perforations may line the subaxial sutures.

Type species.—*Arkhangelskiella concava* GARTNER, 1965.

Remarks.—*Gartnerago* is distinguished from *Arkhangelskiella* and *Broinsonia* by the construction of its multi-tiered rim. In proximal view, *Gartnerago* has a broad inner tier of regular, narrow elements not found in the other genera. The interelement sutures are more inclined and even reverse inclination in the inner tier of *Gartnerago* is seen. A greater number of elements occurs in each tier of the new genus than in those of *Arkhangelskiella* and *Broinsonia*. The third tier may be an extension of the inner one. This construction is unlike the 3 proximal rims of *Arkhangelskiella* and *Broinsonia*, which have regular interelement sutures present at 3 distinct levels. *Gartnerago* is distinguished from *Kamptnerius* by its lack of an asymmetric outer rim cycle.

Occurrence.—Known range, Coniacian-Campanian.

GARTNERAGO CONCAVUM (Gartner), Bukry, n. comb.

Arkhangelskiella concava GARTNER, 1968, p. 37, pl. 14, fig. 2-3; pl. 16, fig. 5-7; pl. 17, fig. 7a-d; pl. 18, fig. 22-23; pl. 19, fig. 6a-d; pl. 21, fig. 7a-c; pl. 22, fig. 13-15.

Remarks.—At least 3 closely appressed rim cycles or tiers are seen in this form. The subaxial sutures on both distal and proximal surfaces are recessed between ridges formed by sloping terminal faces of central-area elements. The presence of distal central-area pits along secondary sutures is a variable property. Perforations are never present but some specimens lack pits. This is the only imperforate species described in the genus. *G. concavum* may be conspecific with *Discolithus segmentatum* STOVER.

Size.—Maximum diameter, 12.8 μ.

Types.—Hypotypes, UI-H-3224 through UI-H-3231.

Occurrence.—Localities and samples, *B-8, B-22, C-4, LW-1, LW-2, LW-4, N-100, PB-50, PH-8, PS-1, PSA, PT-6, Q-6, S-1, S-3, S-4, S-6, S-10, S-11, 42a, 42g*. Known range, Coniacian-Campanian.

Illustrations.—Plate 4, figures 2-6; 2, UI-H-3227, *B-8*, distal, ×6180; 3, UI-H-3224, *42a*, distal, ×5950; 4, UI-H-3230, *S-1*, distal, ×5810; 5, UI-H-3226, *B-8*, proximal, ×9440; 6, UI-H-3225, *S-4*, proximal, ×5810.

GARTNERAGO COSTATUM COSTATUM (Gartner), Bukry, n. comb.

Arkhangelskiella costata GARTNER, 1968, p. 37, pl. 8, fig. 1-3; pl. 11, 1a-c; pl. 28, fig. 2.

Remarks.—This species differs from *Gartnerago concavum* (GARTNER) in having perforations along flanks of the subaxial sutures. The perforations have a single transverse crossbar bisecting them. The bars are at the proximal surface level of the central area. They are formed by the joining of 2 processes, usually at the center of the perforations. Usually a single row of 7 perforations occurs on each side of the long axis of the ellipse. Rows of 8, 9, and 10 have been noted. The specimens studied here are generally larger than those originally described.

Size.—Maximum diameter, 11 μ.

Types.—Hypotypes, UI-H-3232 through UI-H-3236.

Occurrence.—Localities and samples, *LW-3, S-10, S-11*. Known range, Santonian-Campanian.

Illustrations.—Plate 4, figures 7-9; 7, UI-H-3236, *S-10*, distal, ×5490; 8, UI-H-3235, *S-10*, proximal, ×6180; 9, UI-H-3232, *S-11*, distal, ×4310.

GARTNERAGO COSTATUM POROLATUM Bukry, n. sp., n. ssp.

Description.—This coccolith ranges in shape from strongly elliptical (eccentricity, 1.6) to slightly elliptical (eccentricity, 1.2). In proximal view 4 or 5 tiers are seen. The perforations flanking the subaxial sutures are wide and spanned by 2 or 3 transverse crossbars, which are not always aligned with the neighboring subaxial suture (Pl. 4, fig. 11). The perforations may be aligned at 45° to a subaxial suture. In proximal view, the small elements arising at the axes form a pronounced ridge. The number of perforations on each side of the long axis of the ellipse is variable, 6, 7, and 8 being equally common. The range observed is 5 to 10 and the mean 7.

Remarks.—The broadened perforations containing 1, 2, and 3 transverse bars distinguish this variety. In proximal view one more rim tier occurs and the axial ridges are more pronounced than in *Gartnerago costatum costatum*. This variety has not been found in the Austin Chalk.

Size.—Maximum diameter, 12.2 μ.

Types.—Holotype, UI-H-3243, distal view (Pl. 4, fig. 11). Primary paratype, UI-H-3237, proximal view (Pl. 4, fig. 10). Other paratypes, UI-H-3237 through UI-H-3242.

Occurrence.—Type stratigraphic source, lower Taylor Marl.

Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 4, figures 10-12; 10, UI-H-3237, *LW-3*, proximal, ×5490. holotype, UI-H-3243, *LW-4*, distal, ×4520. UI-H-3241, *LW-4*, proximal, ×5490.

GARTNERAGO ZIPPERUM Bukry, n. sp.

Description.—An elliptical coccolith that has 2 distinctive rows of small perforations resulting from a zipper-like interfingering of elements. The basic elliptical shape is modified in distal view, for its outline is bowed-out at the termination of the short axis of the ellipse and blunted at the long axis terminations. One double row of perforations traces the long axis of the ellipse. A second shorter row makes a marked angle of 20° counterclockwise with the short axis in distal view (20° clockwise in proximal view). The inner rim tiers are regular ellipses in proximal view; only the peripheral tier shows the bowed-out and blunted outline. The eccentricity of the regular tiers is 1.6. The small, close-set perforations form rows along the long axis numbering 11 to 14 in the specimens studied. Well-preserved specimens have a distinctive dimpled distal surface.

Size.—Maximum diameter, 8.3 μ.

Types.—Holotype, UI-H-3245, distal view (Pl. 5, fig. 1). Primary paratype, UI-H-3248, proximal view (Pl. 5, fig. 2). Other paratypes, UI-H-3244, and UI-H-3246 through UI-H-3249.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 5, figures 1-4; 1, holotype, UI-H-3245, *LW-4*, distal, ×6610; 2, UI-H-3248, *LW-4*, proximal, ×5490; 3, UI-H-3246, *LW-4*, distal, ×6650; 4, UI-H-3244, *LW-4*, proximal, ×8550.

GARTNERAGO sp.

Description.—This large elliptical coccolith has an outline eccentricity of 1.2 to 1.3. The outer rim cycle contains 70 to 77 elements and the central area occupies 73 to 76 percent of the coccolith length. A distinctive series of oblong windows is formed by the proximal rim elements.

Remarks.—This form may be a variety of *Gartnerago concavum* (Gartner).

Size.—Maximum diameter, 12.5 μ.

Figured specimens.—UI-H-3188, UI-H-3190.

Listed specimens.—UI-H-3189.

Occurrence.—Type stratigraphic source, Craie de Sens. Type locality, Sens, France. Locality and sample, *B-15*. Known range, lower Campanian.

Illustrations.—Plate 5, figures 5-6; 5, UI-H-3190, *B-15*, proximal, ×5250; 6, UI-H-3188, *B-15*, proximal, ×4900.

Organ genus KAMPTNERIUS Deflandre, 1959

KAMPTNERIUS MAGNIFICUS MAGNIFICUS Deflandre

Kampterius magnificus Deflandre, 1959, p. 135, pl. 1, fig. 1-4. ——Gorka, 1963, p. 16, pl. 3, figs. 1-3.——Stradner, 1963, p. 178, pl. 2, fig. 3.——Bramlette & Martini, 1964, p. 301, pl. 2, figs. 1-3.——Stover, 1966, p. 144, pl. 4, figs. 28-30.——Gartner, 1968, p. 39, pl. 2, fig. 1-2, etc.

Remarks.—Most Cretaceous, elliptical coccoliths with an asymmetric outer rim flange have been referred to this species. The 4-tiered rim is constructed like that of *Gartnerago* Bukry, n. gen. The relationship to members of Arkhangelskielloideae is emphasized by the checkered subaxial cross in the central area. Proximal, inner rim counts of 60 and 64 elements have been made on hypotype specimens.

Size.—Maximum diameter, 18 μ.

Types.—Hypotypes, UI-H-3250 through UI-H-3254.

Occurrence.—Localities and samples, *B-8, S-10, S-11*. Known range, Turonian-Maastrichtian.

Illustrations.—Plate 5, figures 7-9; 7, UI-H-3250, *S-11*, proximal, ×3590; 8, UI-H-3253, *S-10*, proximal, ×3240; 9, UI-H-3254, *S-10*, proximal, ×3240.

KAMPTNERIUS MAGNIFICUS SCULPTUS Bukry, n. ssp.

Kamptnerius magnificus, Reinhardt, 1966, p. 22, pl. 17, fig. 1-2; pl. 18, fig. 1-2.

Description.—Within the asymmetric flange, formed by the peripheral rim cycle, this is an elliptical form with an eccentricity of 1.4 to 1.6. The central area is convex distally and the rim tilts up distally toward its margin. A distinctive cross occurs in the central area of the proximal side, becoming less wide away from the center and constructed of elements in a checker arrangement. In proximal view 4 rim tiers appear, the inner one composed of about 80 elements (counts of 75 to 81 were made). The outer rim of the holotype has about 80 elements. Single long elements in strong relief fill the central area between the rim and long axis of the central cross. These maintain an orientation approximately perpendicular to the inner margin of the rim.

Remarks.—Distal views show a very rugose shield with only the asymmetric tier visible. Distal-side specimens from the same sample as the proximal holotype give rim counts of 63 to 72 elements.

Size.—Maximum diameter, 18.5 μ.

Types.—Holotype, UI-H-3258, proximal view (Pl. 5, fig. 10). Primary paratype, UI-H-3257, distal view (Pl. 5, fig. 11). Other paratypes, UI-H-3255 through UI-H-3257 and UI-H-3259.

Occurrence.—Type stratigraphic source, Kjölby Gaard chalk (11 m. below Danian). Type locality, Kjölby Gaard, Denmark. Localities and samples, *B-8, B-15, B-22, KG-11*. Known range, Turonian-Maastrichtian.

Illustrations.—Plate 5, figures 10-12; 10, holotype, UI-H-3258, *KG-11*, proximal, ×3880; 11, UI-H-3257, *B-22*, distal, ×6770; 12, UI-H-3259, *B-15*, proximal, ×3880.

KAMPTNERIUS PERCIVALII Bukry, n. sp.

Kamptnerius magnificus Deflandre, Gartner, 1968, *(partim)*, p. 39, pl. 10, fig. 9-10.

Description.—The outer rim cycle of the elliptical (eccentricity 1.3 to 1.4) coccolith is extended into an asymmetric flange typical of all *Kamptnerius* species. The outer rim is formed by 50 to 70 elements with a slight counterclockwise inclination, in proximal view. Four rim tiers are seen in proximal view, the inner one of the holotype formed by 70 elements that imbricate dextrally and incline slightly counterclockwise. The second tier, of 63 elements, has a strong sinistral inclination. The third tier inclines slightly clockwise. A subaxial cross of checker-arranged elements occurs in the central area, the short axis of which is rotated slightly to form 2 acute and 2 obtuse quadrants. The central area is composed of long elements perpendicular to the inner margin of the rim. Countersunk perforations occur along the sutures of these long elements. Three or four cycles of the perforations occur. Recorded counts of them in 3-cycle forms are 51 (holotype), 53, and 54. Counts in 4-cycle forms are 63 and 66.

Remarks.—The relative width of the 4 rim tiers is different in *Kamptnerius percivalii* than in other species of the genus. This species is distinguished from *K. punctatus* STRADNER by more regular ordering of perforations that are set farther apart and by more abrupt elevation change between the rim and central area.

Size.—Maximum diameter, 13.9 μ.

Types.—Holotype, UI-H-3260, proximal view (Pl. 6, fig. 1). Primary paratype, UI-H-3264, distal view (Pl. 6, fig. 2). Other paratypes, UI-H-3261 through UI-H-3264.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 6, figures 1-3; 1, holotype, UI-H-3260, *LW-4*, proximal, ×4200; 2, UI-H-3264, *LW-4*, distal, ×4300; 3, UI-H-3261, *LW-4*, distal, ×3880.

KAMPTNERIUS PUNCTATUS Stradner

Kamptnerius punctatus STRADNER, 1963, p. 177, pl. 2, figs. 3-3a.
Kamptnerius magnificus Deflandre, GARTNER, 1968, (*partim*), p. 39, pl. 16, fig. 18.

Remarks.—Like other forms of *Kamptnerius*, this species has a checker-structure cross in the central area, the short axis of which diverges to a greater degree than does the long axis from the ellipse axes. This creates 2 small and 2 large quadrants. The large number of perforations characterizing this species reflects the quadrant size difference in their distribution. Although STRADNER's original illustration is a diagrammatic drawing, it indicates a large number of perforations. Electron micrographs from the lower Austin Chalk show *Kamptnerius punctatus* to have perforation counts of 55, 60, 77, 84, 85, and 91. Exclusive of the outer rim tier, this species has the same rim structure as *Gartnerago*. Inner rim counts of 63 and 71 are recorded.

Size.—Maximum diameter, 12 μ.

Types.—Hypotypes, UI-H-3265 through UI-H-3267.

Occurrence.—Localities and samples, *S-10, S-11*. Known range, Turonian-Santonian.

Illustrations.—Plate 6, figures 4-5; 4, UI-H-3267, *S-11*, proximal, ×4520; 5, UI-H-3266, *S-11*, ×4520.

Family COCCOLITHACEAE Kamptner, 1928

Organ genus APERTAPETRA Hay, Mohler, & Wade 1966

APERTAPETRA GRONOSA (Stover), Bukry, n. comb.

Cyclolithus gronosus STOVER, 1966, p. 140, pl. 1, fig. 1-3, pl. 8, fig. 1.——GARTNER, 1968, p. 19, pl. 22, fig. 22.

Remarks.—According to the original light-microscope designation, this form possesses 2 appressed rim cycles of about 40 elements and a large, open central area. Although not noted in the original description, the central opening is distinctly more elongate than the coccolith margin. Eccentricities for the holotype figure are 1.1 (margin) and 1.5 (center). Similar pairs of figures for hypotypes are 1.2 and 1.3, 1.5 and 1.6, 1.2 and 1.9, 1.1 and 1.4, and 1.1 and 1.4. The central-area opening occupies 53 to 61 percent of the coccolith length. In distal view, the larger distal rim is composed of 39 to 45 elements imbricated sinistrally and inclined clockwise at the coccolith margin but changed to counterclockwise halfway to the central area. A small part of the cycle lining the central opening is seen in distal view. In proximal view, the rim cycle is composed of 36 to 42 dextrally imbricated elements that incline strongly clockwise. The cycle of 34 to 39 elements that lines the central area rises slightly above the level of the proximal rim. These elements incline counterclockwise.

HAY, MOHLER, & WADE (1966) distinguished *Apertapetra* from *Cyclolithus* by presence in the former of 2 appressed rim cycles and by a cycle lining the central area, readily visible in proximal view. Such structure is well demonstrated by this species.

Size.—Maximum diameter, 13 μ.

Types.—Hypotypes, UI-H-3000 through UI-H-3005.

Occurrence.—Localities and samples, *ALB, B-8, LW-1, LW-3, LW-4, PH-8, S-6*. Known range, Albian-Campanian.

Illustrations.—Plate 6, figures 6-9; 6, UI-H-3005, *LW-4*, distal, ×3880; 7, UI-H-3003, *LW-3*, proximal, ×5490; 8, UI-H-3000, *ALB*, distal, ×3440; 9, UI-H-3002, *LW-4*, proximal, ×5490.

Genus BIDISCUS Bukry, n. gen.

Description.—This small circular coccolith is constructed of 2 monocycle shields, each composed of a small number of radial elements. The proximal shield is a little smaller than the other and both are slightly convex distally. The very small central area shows varied ornamentation. Coccospheres are spherical and constructed of about 16 coccoliths.

Type species.—Bidiscus cruciatus cruciatus BUKRY, n. sp., n. ssp.

Remarks.—This form is fairly common in Upper Cretaceous sediments of Europe and Texas. It may have given rise to the common Tertiary form, *Cyclococcolithus* KAMPTNER, which also possesses 2 circular monocycle shields but has more elements, is larger, has inequant shields, and displays different central-area structure.

BIDISCUS CRUCIATUS CRUCIATUS Bukry, n. sp., n. ssp.

Description.—This is a small circular coccolith (eccentricity, 1.0) composed of 2 single-cycle shields. The distal shield, which is slightly larger than the proximal one, is composed of 12 to 17 (14 mean) flat, wedge-shaped elements that arise at the center of the shield and extend to the margin. Resulting sutures are straight and radial. No significant imbrication is seen. At the center of the distal shield is a flat cross composed of at least 4 elements. These present 4 straight lines in the outer margin. The pattern resulting from the interelement sutures variously resembles an "iron cross," swastika, or a square with diagonals.

Remarks.—The proportionate size of the cross is larger in specimens from mid-Santonian and younger samples. The same size change was noted in specimens from Texas and Europe. Some specimens show a small clockwise inclined, sinistrally imbricated set of elements at the margin of the cross.

Size.—Maximum diameter, 3.4 μ.

Types.—Holotype, UI-H-3006, distal view (Pl. 6, fig. 10). Paratypes, UI-H-3007 through UI-H-3013.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Polk Street at Ten Mile Creek, Dallas, Texas. Localities and samples, *B-8, B-22, F-14, LW-1, LW-2, LW-3, LW-4, N-100, PB-50, PS-1, S-11, SF-11, WR, 42a.* Known range, Santonian-Campanian.

Illustrations.—Plate 6, figures 10-11; 10, holotype, UI-H-3006, *PS-1,* distal, $\times$14,400; 11, UI-H-3011, *SF-11,* distal, $\times$13,200.

BIDISCUS CRUCIATUS MULTICRUCIATUS Bukry, n. sp., n. ssp.

Description.—This subspecies is distinguished by a small secondary set of 4 elements that forms a second central cross with elements having the same orientation as the large central cross and outlining a small square open space at the center. Two specimens with a third intermediate cross oriented diagonally were observed. There are 12 to 15 radial elements in the circular distal shield cycle.

Remarks.—This form has the same size and rim counts as *Bidiscus cruciatus cruciatus* Bukry, n. sp., n. ssp., but bears the second and third cross elements. Its stratigraphic occurrence suggests that it is derived from *B. cruciatus cruciatus.*

Size.—Maximum diameter, 4.8 μ.

Types.—Holotype, UI-H-3017, distal view (Pl. 7, fig. 1). Paratypes, UI-H-3014 through UI-H-3016, and UI-H-3018.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *B-22, LW-3, LW-4, PH-8, WR.* Known range, Santonian-Campanian.

Illustrations.—Plate 6, figure 12; Plate 7, figures 1-2.——Pl. 6, fig. 12, UI-H-3018, *LW-4,* distal, $\times$17,200.——Pl., fig. 1-2; 1, holotype, UI-H-3017, *LW-4,* distal, $\times$17,200; 2, UI-H-3014, *WR,* distal, $\times$12,500.

BIDISCUS MONOCAVUS Bukry, n. sp.

Description.—A circular coccolith, this form has a small circular perforation at the center. In distal view, the rim cycle is seen to compose most of the shield surface, which has 18 to 24 sinistrally imbricated and radially aligned elements in the rim cycle of specimens studied. A narrow depressed inner cycle of 18 to 22 elements inclined slightly counterclockwise surrounds the central opening. In proximal view, the proximal shield is composed of 17 to 21 sinistrally imbricated elements. The element sutures reverse inclinations. The circular central opening occupies 15 to 18 percent of the coccolith diameter.

Remarks.—This is the only species of *Bidiscus* with a central perforation.

Size.—Maximum diameter, 4.5 μ.

Types.—Holotype, UI-H-3019, distal view (Pl. 7, fig. 3). Primary paratype, UI-H-3020, proximal view (Pl.-7, fig. 4). Other paratypes, UI-H-3020 through UI-H-3022.

Occurrence.—Type stratigraphic source, upper Niobrara Formation. Type locality, Knox County, Nebraska. Locality and sample, *N-100.* Known range, Santonian.

Illustrations.—Plate 7, figures 3-4; 3, holotype, UI-H-3019, *N-100,* distal, $\times$13,500; 4, UI-H-3020, *N-100,* proximal, $\times$11,500.

BIDISCUS ROTATORIUS Bukry, n. sp.

Description.—This is a circular, 2-shield coccolith with an eccentricity of 1.0. The distal shield is slightly larger than the proximal and is composed of a single cycle of 16 to 23 wedge-shaped elements; the mean number of segments is 20. The elements have radial sutures. The circular central area occupies about 0.3 of the diameter of the distal shield. Small elements in the central area are variously ordered or irregular. Well-ordered forms have about 12 sinistrally imbricated oblong elements. The proximal shield has 12 to 23 radially oriented elements that are widest at the margin. The central area is reduced to a small identation. Coccosphere remnants show that this coccolithophore probably had a spherical envelope of about 16 coccoliths imbricated so that half of the rim cycle breadth is overlapped by adjacent coccoliths.

Remarks.—This form is distinguished from other *Bidiscus* species by higher element counts and by the whorl of elements in the central area.

Size.—Maximum diameter, coccosphere, 9 μ; coccoliths, 4.3 μ.

Types.—Holotype, UI-H-3024, distal view (Pl. 7, fig. 5). Primary paratype, UI-H-3026, proximal view (Pl. 7, fig. 9). Other paratypes, UI-H-3023, UI-H-3025 through UI-H-3030.

Occurrence.—Type stratigraphic source, upper Niobrara Formation. Type locality, Knox County, Nebraska. Localities and samples, *ALB, B-8, B-22, F-14, LW-1, LW-2, LW-4, N-100, PT-6, S-1, S-3, S-4, S-10, WR, 42a.* Known range, Albian-Campanian.

Illustrations.—Plate 7, figures 5-9; 5, holotype, UI-H-3024, *N-100,* distal, $\times$5490; 6, UI-H-3027, *LW-1,* distal, $\times$7600; 7, UI-H-3029, *S-1,* distal, $\times$13,600; 8, UI-H-3025, *B-8,* proximal, $\times$9500; 9, UI-H-3026, *LW-1,* distal, $\times$11,500.

Genus BISCUTUM Black, 1959

BISCUTUM ASYMMETRICUM Bukry, n. sp.

Description.—The outline of this elliptical coccolith has an eccentricity of 1.1 to 1.3. In proximal view the rim of the large distal shield has 14 to 26 (20 mean) radially oriented elements. The proximal shield is only 75 to 90 percent (80 percent mean) as long as the distal shield. There are 13 to 24 (19 mean) elements in the rim of the proximal shield. These are thickened at the cycle margin and form an adcentrally sloping surface to a small central area of a few irregular elements. At one end of the proximal shield, the rim elements are enlarged, being distinctly wider and "higher" than the other members of the cycle.

Remarks.—Distal views of this form are not recognized yet. The central area is usually closed but may have a small perforation. The asymmetrical enlargement of one portion of the proximal rim is distinctive.

Size.—Maximum diameter, 4.1 μ.

Types.—Holotype, UI-H-3035, proximal view (Pl. 7, fig. 10). Paratypes, UI-H-3031 through UI-H-3034, UI-H-3036.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Polk Street at Ten Mile Creek, Dallas, Texas. Localities and samples, *LW-1, LW-2, PH-8, PSA, PT-6, Q-6, S-1, S-3, WR.* Known range, Santonian.

Illustrations.—Plate 7, figures 10-11; 10, holotype, UI-H-3035, *PSA,* proximal, ×13,500; 11, UI-H-3034, *PT-6,* proximal, ×13,500.

BISCUTUM BLACKI Gartner

Biscutum blacki GARTNER, 1968, p. 18, pl. 1, fig. 7; pl. 6, fig. 2; pl. 8, fig. 8-10; pl. 11, fig. 8; pl. 15, fig. 2.

Remarks.—This form has a larger, more irregular central area than *Biscutum testudinarium* BLACK. A tiny central perforation is flanked by 4 or 5 larger elements. The larger, distal shield is composed of 19 to 30 elements and the smaller proximal one about 20 elements. A proximal view of a partial coccosphere illustrates coccolith imbrication (Pl. 8, fig. 3). Most of the specimens studied are from the Taylor Marl. Albian specimens are more elongate than the Taylor specimens.

Size.—Maximum diameter, 9.3 μ.

Types.—Hypotypes, UI-H-3037 through UI-H-3041, UI-H-3608.

Occurrence.—Localities and samples, *ALB, LW-3, LW-4.* Known range, Albian-Campanian.

Illustrations.—Plate 7, figure 12; Plate 8, figures 1-3.——Pl. 7, fig. 12, UI-H-3608, *ALB,* proximal, ×8050.——Pl. 8, fig. 1-3; 1, UI-H-3037, *ALB,* proximal, ×13,200; 2, UI-H-3038, *LW-4,* proximal, ×7300; 3, UI-H-3041, *LW-4,* proximal, ×6180.

BISCUTUM MULTIFORME Bukry, n. sp.

Description.—The outline of this form is variously rhombic, hexagonal, or elliptical. In proximal view the distal shield is composed of 21 to 29 (26 mean) radial elements, those at ends of the long axis being larger and more wedge-shaped than the others in the cycle. The proximal shield is notably smaller than the distal shield. Smallest shields are only 40 to 75 percent as long as the distal shield. There are 22 to 29 (24 mean) slightly counterclockwise inclined elements in the planar rim cycle, which is distinctive in having long elements at one end of the shield. The elements become progressively shorter until at the opposite end of the coccolith they are only half as long. The central area is composed of a dextrally imbricated cycle of 8 to 14 (10 mean) large, flat elements. Of the total length of the coccolith 28 to 40 percent (35 percent mean) is occupied by the serrate-margined central area.

Remarks.—The asymmetrical proximal shield and high rim counts separate this form from related species of *Biscutum.* The central area of distinctly imbricating flat elements is also distinctive. Only one proximal view of this new species was recognized.

Size.—Maximum diameter, 5.2 μ.

Types.—Holotype, UI-H-3046, proximal view (Pl. 8, fig. 4). Primary paratype, UI-H-3043, distal view (Pl. 8, fig. 5). Other paratypes, UI-H-3042 through UI-H-3045, UI-H-3047 through UI-H-3049.

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Localities and samples, *B-8, C-4, F-14, KG-11, LW-2, N-100, SF-10, SF-11, 42g.* Known range, Coniacian-Maastrichtian.

Illustrations.—Plate 8, figures 4-6; 4, holotype, UI-H-3046, *B-8,* proximal, ×10,800; 5, UI-H-3043, *F-14,* distal, ×10,400; 6, UI-H-3609, *B-8,* proximal, ×9500.

BISCUTUM TESTUDINARIUM Black

Biscutum testudinarium BLACK in BLACK & BARNES, 1959, p. 325, pl. 10, fig. 1.

Biscutum castrorum BLACK, ibid., p. 326, pl. 10, fig. 2.

Cribrosphaerella tectiforma REINHARDT, 1964, Wiss., Berlin, p. 758, pl. 2, fig. 4.

Coccolitites polycingulatus REINHARDT, 1965, p. 39, pl. 3, fig. 4.

Biscutum testudinarium, REINHARDT, 1966, p. 19, pl. 12, fig. 1.

Cribrosphaera tectiforma REINHARDT, 1966, p. 30, pl. 5, fig. 3a-b; pl. 12, fig. 3-4; text-fig. 12.

Remarks.—The genus *Biscutum* BLACK was established for the proximal views of coccoliths with 2 closely appressed shields. In the original designation 2 species were named. The distinctions noted are probably only intraspecific in nature (slight size, rim count, and element rounding differences). Therefore, *B. castrorum* BLACK is considered synonomous with the type species, *B. testudinarium* BLACK. Distal views of this form were first illustrated by REINHARDT, who named this form *Cribrosphaerella tectiforma* in 1964 and *Coccolithites polycingulatus* in 1965. In comparing specimens attributable to these proximal and distal view taxa, striking similarites in rim and central area structures and counts show that *B. testudinarium* specimens are proximal views of *Cribrosphaerella tectiforma* specimens. For the sake of continuity, a redescription of the species *B. testudinarium* is provided.

Proximal and distal views of this elliptical coccolith have eccentricities 1.0 to 1.4 (1.2 mean). In distal view, the rim cycle is composed of 14 to 22 (17 mean) elements that are radial. Two large wedge-shaped elements occur at ends of the ellipse. The elements along the long sides are narrow, with nearly parallel sutures. These side elements have a tab on the inner portion of their sinistral suture that fits into a notch on the dextral side of the adjacent element. The elliptical central area occupies 36 to 50 percent (44 percent mean) of the coccolith length. The outer rim surface is an adcentrally sloping surface. The central-area cycle of 10 to 15 (12 mean elements form a "berm" below the rim cycle inner margin. The major faces in the central-area cycle also slope adcentrally. This results in a distinct depression in the central area which may be closed or slightly open. In proximal view, the proximal shield is seen to be of variable size but always smaller than the distal shield. The rim cycle is composed of 14 to 20 (17 mean) elements that are radial to inclined slightly counterclockwise. Here too, are large wedge-shaped elements at ends of the elliptical rim outline that has eccentricity of 1.0 to 1.4 (1.2 mean). The central area is composed of 9 to 15 (11 mean) small elements symmetric to the long axis of the ellipse. The central area occupies 22 to 33 percent (31 percent mean) of the total coccolith length. The main clue to uniting the proximal and distal views of this form is the set of wedge-shaped elements at ends of the shields which can both be seen in proximal view. Two coccospheres were observed from the lower Austin Chalk.

Size.—Maximum diameter, 6.6 μ.

Types.—Hypotypes, UI-H-3050 through UI-H-3054, UI-H-3610.

Occurrence.—Localities and samples, *B-8, B-22, LW-1, LW-3, LW-4, N-11+8, PB-50, PH-8, PT6, Q-6, S-1, S-2, S-3, S-10, S-11, SF-11, WR, 42a.* Known range, Albian-Campanian.

Illustrations.—Plate 8, figures 7-12; 7, UI-H-3051, *B-8,* distal, ×8550; 8, UI-H-3050, *B-8,* proximal, ×8080; 9, UI-H-3054, *S-3,* distal, ×4850; 10, UI-H-3610, *B-8,* distal, ×7130; 11, UI-H-3052, *B-8,* proximal, ×6460; 12, UI-H-3053, *S-3,* distal, ×12,800.

Organ genus CYCLAGELOSPHAERA Noël, 1965

CYCLAGELOSPHAERA BATICLYPEATA Bukry, n. sp.

Description.—This approximately circular coccolith has a marginal eccentricity of 1.1, while the central area has an eccentricity of 1.3. The broad rim cycle is composed of 34 elements that imbricate dextrally and incline very slightly counterclockwise. A very narrow inner cycle contains 34 radially oriented blocky elements. The large central area is a radial grill of 18 long, narrow elements that meet near the center of the central area. Separations between them are equal to the width of the elements. The central area occupies 57 percent of the longest diameter of the coccolith.

Remarks.—This form is distinguished from the comparable *Cyclagelosphaera rotaclypeata* Bukry, n. sp., by its small size, large central area, and long equally separated elements within the central area.

Size.—Maximum diameter, 4 μ.

Types.—Holotype, UI-H-3064, distal view (Pl. 9, fig. 1).

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4.* Known range, Campanian.

Illustrations.—Plate 9, figure 1, holotype, UI-H-3064, *LW-4,* distal, ×12,900.

CYCLAGELOSPHAERA? CHRONOLITHA Bukry, n. sp.

Description.—This essentially circular (eccentricity, 1.0 to 1.1), complex coccolith has the general appearance of a Mexican calendar stone. In proximal view, the proximal shield is 71 to 82 percent (76 percent mean) as large as the distal shield. Three cycles of elements can be counted on the proximal shield. The central area is composed of a cycle of 37 to 45 (41 mean) elements that imbricate slightly dextrally and incline counterclockwise. A few irregular elements occur at the actual center, and the outer margin of the central area is formed by a slight scalloping of the next cycle. This second cycle of 30 to 45 (40 mean) elements is contradistinctive in its clockwise inclinations. The outer cycle of the shield may be obscured by blocky overgrowths, but contains 34, 38, and 42 elements in good specimens. These elements imbricate dextrally and incline counterclockwise. The rim cycle of the distal shield, seen in proximal and distal views, is composed of 35 to 50 (41 mean) elements that are radially oriented. Mean proportions of the 3 distinct peripheries seen in proximal view are: central area to proximal shield 38 percent, central area to distal shield 29 percent, and proximal shield to distal shield 76 percent.

Remarks.—The distinctive formation of the 2 inner cycles of the proximal shield, plus the combination of size and rim counts serve to distinguish this form from other circular coccoliths.

Size.—Maximum diameter, 9.1 μ.

Types.—Holotype, UI-H-3068, proximal view (Pl. 9, fig. 2). Primary paratype, UI-H-3067, distal view (Pl. 9, fig. 3). Other paratypes, UI-H-3065 through UI-H-3067, UI-H-3069.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, South Dallas County, Texas. Localities and samples, *PS-1, Q-6, S-1, S-3, S-11.* Known range, lower Santonian.

Illustrations.—Plate 9, figures 2-4; 2, holotype, UI-H-3068, *S-3,* proximal, ×6460; 3, UI-H-3067, *S-1,* distal, ×6140; 4, UI-H-3066, *S-11,* proximal, ×6140.

CYCLAGELOSPHAERA MARGERELI Noël

Cyclagelosphaera margereli Noël, 1965, p. 130, text-fig. 44-46; pl. 17, fig. 4-9; pl. 18, fig. 1-2; pl. 20, fig. 2-4.——Maresch, 1966, p. 380, pl. 2, fig. 5.

Coccolithus sp. Black, 1965, v. 24, no. 93, p. 132, fig. 7.

Remarks.—This essentially circular form has 3 cycles of elements visible in distal view. The outer-cycle elements imbricate dextrally and incline counterclockwise. The next inner cycle has dextrally imbricated elements that incline slightly clockwise. Finally, a small irregular cycle of elements may have a central perforation or completely close the central area. Published rim counts of the outer cycle are 19 to 24. Counts for the inner cycle are 17 to 22. The specimens figured here have 29 elements in the outer cycle and 21 in the inner cycle. The broad rim cycle of the smaller proximal shield is composed of 26 elements that incline slightly counterclockwise. *Cyclagelosphaera margereli* is related by element shape and counts to the *Watznaueria barnesae* (BLACK) type of coccolith.

Size.—Maximum diameter, 10 μ.

Types.—Hypotypes, UI-H-3070 and UI-H-3071.

Occurrence.—Localities and samples, *ALB, PB-50.* Known range, Oxfordian-Santonian.

Illustrations.—Plate 9, figures 5-6; 5, UI-H-3070, *ALB,* distal, ×7800; 6, UI-H-3071, *PB-50,* proximal, ×7130.

CYCLAGELOSPHAERA ROTACLYPEATA Bukry, n. sp.

Description.—The outline of this coccolith is essentially circular, with eccentricities of 1.0 to 1.2. The broad rim cycle is composed of 27 to 40 (33 mean) elements that imbricate dextrally and incline counterclockwise (one of the eight specimens is sinistral and clockwise). A very narrow, depressed inner cycle contains 23 to 40 (31 mean) elements that are radial. The central area is filled by 9 to 22 (15 mean) radially arranged, irregular elements. Usually, 8 to 11 of these are enlarged and dominate the central-area cycle. These dominant elements are typically wedge- or club-shaped, with widest portion of the element at the center. The narrow, tapered ends are at the margin of the central area. Eccentricities of the central area range from 1.0 to 1.3. The central area occupies 35 to 50 percent (44 percent mean) of the long diameter of the coccolith.

Remarks.—The smaller, closed central area with club-shaped elements separates this form from *Cyclagelosphaera baticlypeata* BUKRY, n. sp. The comparable *C. specioclypeata* BUKRY, n. sp., has a smaller central area and a wider second cycle in distal view. The outer cycle has a nonplanar slope in that species.

Size.—Maximum diameter, 6.4 μ.

Types.—Holotype, UI-H-3075, distal view (Pl. 9, fig. 8). Paratypes, UI-H-3072 through UI-H-3074.

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *B-8, LW-1, PT-6, N-100, S-3.* Known range, Santonian-Campanian.

Illustrations.—Plate 9, figures 7-8; 7, UI-H-3073, *B-8,* distal, ×10,900; 8, holotype, UI-H-3075, *LW-1,* distal, ×8080.

CYCLAGELOSPHAERA SPECIOCLYPEATA Bukry, n. sp.

Description.—This circular coccolith has marginal and central-area eccentricities of 1.0. In distal view, the sloping rim cycle elements appear to broaden and do flatten at the inner margin of the cycle. There are 31 dextrally imbricate and counterclockwise inclined elements in the cycle. A broad, inner cycle of 31 slightly clockwise inclined elements slopes in the opposite direction (adcentrally) toward the central area. The circular central area is made of about 20 polygonal elements. Four of these are larger than the others and form a roughly orthogonal cross. Between the elements are 5 others of secondary size and a lesser group that completely fills the central area, which occupies only 30 percent of the length of any diameter of the coccolith.

Remarks.—The break in the slope of the rim cycle, broad inner cycle, and small central area distinguish this form from the comparable *Cyclagelosphaera rotaclypeata* BUKRY, n. sp.

Size.—Maximum diameter, 7.4 μ.

Types.—Holotype, UI-H-3076, distal view (Pl. 9, fig. 9).

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4.* Known range, Campanian.

Illustration.—Plate 9, figure 9, holotype, UI-H-3076, *LW-4.* distal, ×7130.

Genus CYCLOCOCCOLITHUS Kamptner, 1958

CYCLOCOCCOLITHUS? WAXAHACHIA Bukry, n. sp.

Description.—This is a circular, 2-shield coccolith with 3 distinct cycles of narrow elements. In proximal view, the distal shield cycle has 30 elements that incline counterclockwise and imbricate dextrally. The proximal shield rim cycle also has 30 elements that imbricate dextrally, but incline very slightly clockwise. The central area of the proximal shield is composed of a cycle of 31 elements which have a slight sinistral imbrication and slight clockwise inclination. The respective diameters of the 3 cycles are, 8.8 μ, 8.1 μ, and 2.4 μ.

Remarks.—Though this form is structurally assignable to *Cyclococcolithus,* definite assignment requires the extinction of the distal shield in crossed-nicol, light microscope examination. *C. inversus* DEFLANDRE, figured in an electron micrograph by HAY, MOHLER, & WADE (1966), is a structurally comparable form. *C.? waxahachia* is distinguished by a proportionally smaller central area, by its opposite inclination of the 2 inner cycle elements, and by having proximal and distal shields of approximately the same size.

Size.—Maximum diameter, 8.8 μ.

Types.—Holotype, UI-H-3077, proximal view (Pl. 9, fig. 10).

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4.* Known range, Campanian.

Illustration.—Plate 9, figure 10, holotype, UI-H-3077, *LW-4,* proximal, ×5490.

Organ genus SIMILICORONILITHUS Bukry, n. gen.

Description.—This circular coccolith is composed of 2 or 3 shields, each composed of a single cycle of inclined elements. The shields are quite planar with smooth margins. The proximal shields are considerably larger than the distal ones which mirror the structure of the adjacent shield. The distal shield is presumed to be slightly elevated.

Type species.—*Similicoronilithus primus* BUKRY, n. sp.

Remarks.—*Similicoronilithus* is similar to *Bidiscus* in being planar, circular and in having each shield composed of single cycle of elements. It differs in having a central area structure slightly elevated above and mirroring the structure of the adjacent shield.

SIMILICORONILITHUS PRIMUS Bukry, n. sp.

Description.—This unusual coccolith has an approximately circular outline with maximum eccentricity of 1.1. The broad, visible proximal rim is composed of a single cycle of 35 straight-sutured elements that imbricate dextrally and incline counterclockwise. A slightly smaller, second proximal shield is inferred from a partial trace showing through the distal shield's replica-image. The central area of the visible proximal shield is covered by a similarly constructed shield that forms a very slightly elevated crown. This small distal shield is completely composed of a single rim cycle of 32 elements that imbricate sinistrally and incline clockwise. This smaller shield just covers the central area of the visible proximal shield and occupies 40 percent of its long diameter.

Remarks.—Lack of any shadowing around the small central shield indicates that it is very close to the level of the visible proximal shield.

Size.—Maximum diameter, 7.8 μ.

Types.—Holotype, UI-H-3078, distal view (Pl. 9, fig. 11).

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Locality and sample, *B-8*. Known range, Campanian.

Illustration.—Plate 9, figure 11, holotype, UI-H-3078, *B-8*, distal, ×5810.

Genus WATZNAUERIA Reinhardt, 1964

Remarks.—These elliptical coccoliths are constructed of 2 rim cycles and a central area cycle that is variously modified. The center may be open or closed. Though species of *Watznaueria* bear structural resemblance to *Coccolithus* SCHWARZ, it is noted by HAY, MOHLER & WADE (1966) that the distal shield of *Coccolithus* has "all of the calcite segments oriented so that the C-axes are perpendicular, or very nearly so, to the plane of the shield." In polarized-light microscopy this orientation means that "only the proximal shield produces an interference figure, the distal shield is dark." *Watznaueria* is distinguished by the heliolithid character of the distal shield. A light-microscope check of samples *LW-4* and *S-10* confirmed the presence of *Watznaueria* species on this basis and the absence of *Coccolithus* species.

WATZNAUERIA ACTINOSA (Stover), Bukry, n. comb.

Coccolithus actinosus STOVER, 1966, p. 138, pl. 1, fig. 15-16; pl. 8, fig. 7.

Remarks.—In outline, this form is usually a slightly irregular ellipse. Electron micrographs reveal a narrow cycle of 23 elements between the distal shield rim and the central area. These imbricate dextrally and their sutures incline clockwise in distal view. The number of perforations observed in the central area is 7 to 10. The axial cross structure in STOVER's figures is an optical effect, for no cross structure was observed in electron micrographs. Distinction of this form from *Watznaueria paenepelagica* (STOVER) is based on the large number of perforations in the central area.

Size.—Maximum diameter, 4.8 μ.

Types.—Hypotypes, UI-H-3079, UI-H-3080.

Occurrence.—Locality and sample, *LW-4*. Known range, Neocomian-Campanian.

Illustration.—Plate 9, figure 12, UI-H-3080, *LW-4*, distal, ×10,800.

WATZNAUERIA BARNESAE (Black), Bukry, n. comb.

Tremalithus barnesae BLACK in BLACK & BARNES, 1959, p. 325, pl. 9, figs. 1-2.

Coccolithus cf. *C. barnesae* (BLACK), BRAMLETTE & MARTINI, 1964, p. 298, pl. 1, figs. 13-14.

Colvillea barnesae (BLACK), BLACK, 1964, p. 311.

Tergestiella barnesae (BLACK, 1959) REINHARDT, 1964, p. 753.

Watznaueria angustoralis REINHARDT, 1964, p. 753, pl. 2, fig. 2, text-fig. 4.

Ellipsagelosphaera frequens NOËL, 1965, p. 119, pl. 11, fig. 7-10, pl. 12, fig. 1-10, pl. 13, fig. 1-10, text-fig. 35-40.

Colvillea barnesae, BLACK, 1965, p. 132, fig. 2.

Maslovella barnesae (BLACK) TAPPAN & LOEBLICH, 1966, p. 43.

Watznaueria angustoralis REINHARDT, 1966, p. 522, pl. 1, fig. 9, 12; text-fig. 3, 8.———REINHARDT, 1966, p. 16, pl. 2, fig. 2; pl. 3, fig. 1-3; pl. 23, fig. 4; text-fig. 5 a-b.

Coccolithus barnesae (BLACK), GARTNER, 1968, p. 17, pl. 1, fig. 12, pl. 4, figs. 6-7, pl. 8, figs. 18-22, etc.

Remarks.—This form is very abundant throughout the Late Cretaceous and shows more variety in rim count and central-area structure than was estimated in the original description. This was recognized by BRAMLETTE & MARTINI (1964) and by GARTNER (1968). Other workers, attempting to apply strict definitions to this form on the basis of limited samples, have proliferated synonyms.

On the basis of 150 specimens from samples ranging from Albian to Maastrichtian, a number of varieties assignable to *Watznaueria barnesae* (BLACK) were observed. In the basic form, described by BLACK, the innermost cycle of elements is depressed (Pl. 10, fig. 3). In another common variety this inner cycle has the elements elevated above the level of the distal shield (Pl. 10, fig. 1). In both varieties the inner cycle can close the center completely, leave a conical depression or bound a complete perforation at the center of the shield. A less common variety with large, disordered elements in the central area is observed. In distal view, the outer cycle elements imbricate dextrally and incline counterclockwise. The second cycle is also dextrally imbricated and very slightly inclined clockwise. In proximal view, the proximal shield has a serrate margin and is composed of a single cycle of elements, which imbricate sinistrally and incline very slightly counterclockwise. The proximal side of the distal shield shows the interelement sutures of the rim cycle to be radial to slightly counterclockwise in inclination. Specimens from samples *B-15, SF-10, SF-11,* and *42a* have the inner ends of several proximal shield elements greatly enlarged into clubs (Pl. 10, fig. 6).

REINHARDT (1964) figured *Watznaueria barnesae* as the type species of a new genus, *Watznaueria*. He called it *W. angustoralis*, n. sp. Actually, *W. angustoralis*= *W. barnesae*, the type of *Watznaueria*.

Size.—Maximum diameter, 7 μ.

Types.—Hypotypes, UI-H-3081 through UI-H-3100.

Occurrence.—Localities and samples, *ALB, B-8, B-15, B-22, KG-11, LW-1, LW-2, LW-3, LW-4, N-11+8, N-100, PB-50, PH-8, PS-1, PSA, PT-6, Q-3, Q-6, S-1, S-2, S-3, S-4, S-6, S-10, S-11, SF-10, SF-11, 42a, 42g, WR.* Known range, Oxfordian-Maastrichtian.

Illustrations.—Plate 10, figures 1-7; 1, UI-H-3099, *S-1*, distal, ×3230; 2, UI-H-3091, *B-8*, distal, ×5170; 3, UI-H-3092, *B-8*, distal and proximal, ×5170; 4, UI-H-3098, *S-1*, distal, ×6140; 5, UI-H-3096, *S-3*, proximal, ×10,100; 6, UI-H-3088, *SF-11*, proximal, ×6460; 7, UI-H-3093, *B-8*, distal, ×8550.

WATZNAUERIA BIPORTA Bukry, n. sp.

Description.—This is a smooth-outlined, elliptical coccolith with eccentricity of 1.2 to 1.3. Proximal and distal shield rim counts are both about 40 elements. In proximal view, the proximal rim elements incline counterclockwise and imbricate slightly sinistrally. The distal shield elements incline clockwise and imbricate sinistrally. Two large perforations with remnants? of intruding processes characterize the central area. Interelement sutures in the central area are undulatory and diagonal across the area between the perforations.

Remarks.—The 2 large perforations with several processes and diagonally arranged central area elements distinguish this form.

Size.—Maximum diameter, 10.8 μ.

Types.—Holotype, UI-H-3102, proximal view (Pl. 10, fig. 8). Primary paratype, UI-H-3104, distal view (Pl. 10, fig. 9). Other paratypes, UI-H-3101, UI-H-3103, UI-H-3104.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 10, figures 8-10; 8, holotype, UI-H-3102, *LW-4*, proximal, ×5810; 9, UI-H-3104, *LW-4*, distal, ×5490; 10, UI-H-3103, *LW-4*, proximal, ×6650.

WATZNAUERIA CORONATA (Gartner) emend., Bukry, n. comb.

Coccolithus coronatus GARTNER, 1968, p. 17, pl. 23, figs. 26-28.

Remarks.—An elliptical coccolith with smooth margin of the distal shield and that of the proximal shield smooth, serrate, or scalloped. The eccentricity is 1.1 to 1.3. Rim counts of 23 to 32 are observed, about 30 most common. In proximal view, a short, narrow dextrally imbricated tab appears on each element of the proximal rim at the inner margin of the cycle. An even narrower cycle of small elements occurs just inside this tab circuit right at the border of the central area. A cycle of narrow elements, roughly perpendicular to the rim cycle margin and meeting at a slit aligned to the long axis in the center, forms the central-area structure. The slit is usually closed. The original figures do not include a good distal view, but figures presented here (Pl. 10, fig. 11; Pl. 11, fig. 1) show the same central slit and structure as the proximal views. The latter differ from original illustrations in showing the presence of tabs and a cycle of narrow elements around the central area.

Size.—Maximum diameter, 7.4 μ.

Types.—Hypotypes, UI-H-3105 through UI-H-3112.

Occurrence.—Localities and samples, *B-8, LW-4, N-100, S-10.* Known range, Santonian-Campanian.

Illustrations.—Plate 10, figures 11-12; Plate 11, figures 1-2. ——Pl. 10, fig. 11-12; 11, UI-H-3109, *S-10*, distal, ×8080; 12, UI-H-3105, *LW-4*, proximal, ×9440.——Pl. 11, fig. 1-2; 1, UI-H-3111, *B-8*, distal, ×9500; 2, UI-H-3110, *S-10*, proximal, ×6460.

WATZNAUERIA MARTELAE (Noël), Bukry, n. comb.

Calolithus martelae NOËL, 1965, p. 135, pl. 14, fig. 1-10; pl. 15, fig. 1-6.

Remarks.—The distinctive notching of elements that produces a circuit of perforations at the central-area margin is well illustrated in Campanian specimens. Rim counts and inclinations match the original specimens.

Size.—Maximum diameter, 8.1 μ.

Types.—Hypotypes ,UI-H-3116 through UI-H-3120.

Occurrence.—Localities and samples, *B-22, LW-2, LW-3, LW-4, ?Q-3.* Known range, Oxfordian-Campanian.

Illustrations.—Plate 10, figures 3-5; 3, UI-H-3117, *LW-4*, proximal, ×9030; 4, UI-H-3120, *LW-4*, distal, ×6140; 5, UI-H-3119, *LW-4*, proximal, ×8080.

WATZNAUERIA MASTERSII Bukry, n. sp.

Description.—The eccentricity of this form is 1.3. In distal view the rim cycle has 22 and 25 elements in specimens available having radial sutures and no significant imbrication. A slightly depressed central area is bordered by narrow faces of the rim elements. The open central area has a large cycle of small elements around a central opening. This structure could be the base of a hollow stem. Because of the circular nature of this central cycle and the oval shape of the central area, 2 small perforations flank the central cycle along the long ellipse axis of the coccolith.

Remarks.—Although this form is quite distinctive in features of its central area, the exact structure of this area is yet undetermined.

Size.—Maximum diameter, 4.3 μ.

Types.—Holotype, UI-H-3114, distal view (Pl. 11, fig. 6). Paratype, UI-H-3115.

Occurrence.—Type stratigraphic source, upper Niobrara Formation. Type locality, Knox County, Nebraska. Locality and sample, *N-100*. Known range, Santonian.

Illustrations.—Plate 11, figures 6-7; 6, holotype, UI-H-3114, *N-100,* distal, ×13,800; 7, UI-H-3115, *N-100,* distal, ×13,500.

WATZNAUERIA OBLONGA Bukry, n. sp.

Description.—This form has a distinctly oblong central area. Eccentricity of the margin of the coccolith is 1.1 to 1.3. In distal view the rim cycle is composed of 24 to 27 elements that imbricate dextrally and incline slightly counterclockwise. The inner margins of these rim elements form the relatively smooth margin of the recessed central-area structure, in which is a border cycle of about 18 small elements that imbricate sinistrally and incline counterclockwise. A broad low-relief offset X-shaped cross occupies most of the center of the central area. The cross is symmetric to the axes of the ellipse. The central area elements are relatively large. Two depressions or perforations occur between the central area border cycle and the cross structure at the center.

Remarks.—The offset cross structure is a very low relief feature. This and the oblong central area are distinctive attributes of the species.

Size.—Maximum diameter, 7.6 μ.

Types.—Holotype, UI-H-3121, distal view (Pl. 11, fig. 9). Paratypes, UI-H-3122, UI-H-3123.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, South Dallas County, Texas. Locality and samples, *S-1, S-3, S-4.* Known range, lower Santonian.

Illustrations.—Plate 11, figures 8-10; 8, UI-H-3123, *S-3,* distal, ×6650; 9, holotype, UI-H-3121, *S-4,* distal, ×9500; 10, UI-H-3122, *S-1,* distal, ×7600.

WATZNAUERIA OVATA Bukry, n. sp.

Description.—This elliptical coccolith with eccentricity of 1.2 to 1.5 has a large, oval central opening. In distal view, the outer cycle is composed of 28 to 31 elements that imbricate dextrally and incline counterclockwise. The second cycle overlaps the rim cycle and is made of 24 to 29 dextrally imbricated elements inclined slightly clockwise. The innermost cycle is reduced to a narrow wall of elements (16 in the single specimen countable) lining the central opening, which occupies 21 to 42 percent of the length of the coccolith (mean, 31 percent; holotype, 33 percent). In proximal view, the proximal shield is composed of 24 to 28 elements that imbricate sinistrally and incline slightly counterclockwise. The proximal shield is composed of a single cycle of elements and has about the size of the distal shield.

Remarks.—This form is structurally allied to the *Watznaueria barnesae* group of coccoliths, but is distinct because of its large, smooth central opening. It differs from *Cyclolithella (=Cyclolithus) solidus* (Stover) in its nonscalloped margin and presence of 3 cycles of elements.

Size.—Maximum diameter, 6.3 μ.

Types.—Holotype, UI-H-3128, distal view (Pl. 11, fig. 11). Primary paratype, UI-H-3124, proximal view (Pl. 11, fig. 12). Other paratypes, UI-H-3125 through UI-H-3127, UI-H-3129.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, south, Dallas County, Texas. Localities and samples, *LW-1, LW-2, PB-50, PT-6, S-3, S-10, S-11.* Known range, Santonian.

Illustrations.—Plate 11, figures 11-12; 11, holotype, UI-H-3128, *PB-50,* distal, ×8750; 12, UI-H-3124, *LW-2,* proximal, ×8550.

WATZNAUERIA PAENEPELAGICA (Stover), Bukry, n. comb.

Coccolithus paenepelagicus Stover, 1966, p. 139, pl. 1, figs. 10-11; pl. 3, fig. 22B; pl. 8, fig. 5.

Remarks.—This species is seen in electron micrographs to be closely related to *Watznaueria actinosa* (Stover). Although the outer rim counts vary from 18 to 28, the cycle and element shape and proportions are similar. A narrow strongly imbricated cycle of elements occurs at the central area margin. Instead of a cycle of perforations, only a single small central opening appears, surrounded by a rosette of small elements.

Size.—Maximum diameter, 4.5 μ.

Types.—Hypotypes, UI-H-3130 through UI-H-3134.

Occurrence.—Localities and samples, *LW-1, LW-2, LW-3, LW-4, N-100, PB-50, PH-8, PSA, S-3, S-4, Q-6, WR, 42a.* Known range, Neocomian-Campanian.

Illustrations.—Plate 12, figures 1-4; 1, UI-H-3132, *N-100,* distal, ×16,400; 2, UI-H-3131, *42a,* distal, ×12,500; 3, UI-H-3134, *LW-4,* distal, ×11,200; 4, UI-H-3133, *LW-4,* distal, ×10,100.

WATZNAUERIA? PARVIDENTATA (Deflandre and Fert), Bukry, n. comb.

Discolithus parvidentatus Deflandre & Fert, 1954, p. 143, text-fig. 28-29.

Tremalithus burwellensis Black & Barnes, 1959, p. 324, pl. 8.

Coccolithus parvidentatus (Deflandre & Fert), Reinhardt, 1966, p. 20, pl. 20, fig. 1-2.

Remarks.—The grid of opposing calcite bars in the central area is at the level of the highest point in the distal shield. In proximal view the bars appear recessed. Varieties with 8 to 24 bars have been observed. The central terminations are always enlarged into knobs. Rim counts of 83 to 108 have been made in both shields. The long, narrow, rim elements are disposed radially with little apparent imbrication. Since the original description, little reference to this form has appeared in the literature. Because of their very small size, specimens may easily be overlooked or lost in preparation. I found it present in practically every sample studied, however.

Size.—Maximum diameter, 4.5 μ.

Types.—Hypotypes, UI-H-3135 through UI-H-3142, UI-H-3611.

Occurrence.—localities and samples, *ALB, B-8, B-22, F-14, LW-3, LW-4, N-0, N-11+8, N-100, PB-50, PSA, PT-6, S-1, S-3, S-4, S-6, S-10, S-11, WR, 42a.* Known range, Albian-Campanian.

Illustrations.—Plate 12, figures 5-8; 5, UI-H-3139, *B-8,* proximal, ×11,900; 6, UI-H-3138, *B-8,* distal, ×9510; 7, UI-H-3142, *LW-4,* distal, ×11,500; 8, UI-H-3611, *LW-4,* proximal, ×16,400.

WATZNAUERIA PORTA Bukry, n. sp.

Description.—In distal view, 3 groups of elements are recognized. An elliptical rim cycle with (eccentricity of

1.2) 25 radial elements shows little imbrication. The inner cycle which has about 22 elements strongly imbricated dextrally and strongly inclined clockwise, is recessed below the elliptical outline of the inner edge of the rim cycle. The inner margin of the inner cycle forms a diamond-shaped outline with apices along the long and short axes of the ellipse. The central area is occupied by a group of small irregular, block elements around a circular opening at the center of the diamond-shaped area. A trace of the proximal shield is visible. This has a radially oriented set of about 21 elements in the outer cycle. The proximal shield is only 80 percent as long as the distal shield.

Size.—Maximum diameter, 3.9 μ.

Type.—Holotype, UI-H-3113, distal view (Pl. 12, fig. 9).

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustration—Plate 12, figure 9, holotype, UI-H-3113, *LW-4* distal, ×13,800.

WATZNAUERIA? PROLONGATA Bukry, n. sp.

Description.—This elongate elliptical form has a margin eccentricity 1.3 to 1.6. In ?distal views, the outer rim cycle is composed of 22 to 34 (29 mean) radial elements with a smaller imposed cycle of 27 to 31 radial elements. Finally, a narrow cycle of 28 to 32 elements lines the open central area, which occupies 50 to 70 percent of the coccolith length. Most specimens have small groups of elements protruding into the central area, suggesting that its original structure has been broken away.

Remarks.—Though its affinities are indefinite, the thick scalloped multilayered elongate rim makes this a distinctive Campanian species.

Size.—Maximum diameter, 4.5 μ.

Types.—Holotype, UI-H-3143, ?distal view (Pl. 12, fig. 10). Paratypes, UI-H-3144 through UI-H-3146.

Occurrence.—Type stratigraphic source, Aachen marl. Type locality, Aachen, Germany. Localities and samples, *B-8, B-22*. Known range, Campanian.

Illustrations.—Plate 12, figures 10-12; 10, holotype, UI-H-3143, *B-22*, distal, ×11,000; 11, UI-H-3145, *B-22*, distal, ×14,700; 12, UI-H-3146, *B-8*, distal, ×11,500.

WATZNAUERIA QUADRIRADIATA Bukry, n. sp.

Description.—A four-armed cross structure occurs in the center of this roughly circular form (eccentricity of holotype, 1.1). In proximal view, the proximal shield is composed of 2 or 3 cycles of elements, the outer one with serrate outline being composed of 25 to 32 elements that have no distinct imbrication and only slight counterclockwise inclination. At the inner margin of this cycle, the elements are extended into tabs on their dextral, dextrally imbricated sides. One or 2 narrow cycles, each composed of 16 to 22 blocky elements, line the oval central opening, which contains an orthogonal cross structure aligned with the ellipse axes. Since the diameter of the rim cycle of the distal shield is larger than that of the proximal one, rim counts of 25 or 26 elements can be made. In the holotype, the central area occupies 30 percent of the greatest diameter of the coccolith.

Remarks.—The tab structure of the proximal shield is seen elsewhere in *Watznaueria coronata* (Gartner). The serrate margin of the proximal shield and smooth margin of the larger, distal shield are typical of the *W. barnesae* (Black) group. The moderate-sized central opening with 1 or 2 lining cycles, the 4-armed cross, and circularity are distinguishing features of *W. quadriradiata*. Most similar to the new species in structure is *W. britannica* (Stradner) but the latter has a single crossbar.

Size.—Maximum diameter, 8.4 μ.

Types.—Holotype, UI-H-3147, proximal view (Pl. 13, fig. 2). Paratypes, UI-H-3148, UI-H-3149.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, Dallas County, Texas. Localities and samples, *PB-50, S-3, S-11*. Known range, Santonian.

Illustrations.—Plate 13, figures 1-3; 1, UI-H-3149, *S-3*, proximal, ×6650; 2, holotype, UI-H-3147, *PB-50*, proximal, ×6650; 3, UI-H-3148, *S-11*, proximal, ×8550.

WATZNAUERIA VIRGINICA Bukry, n. sp.

Description.—This strongly elliptical coccolith has eccentricities of 1.6 to 1.8. The slightly serrate outer rim is composed of 19 or 20 elements that imbricate dextrally and have radial sutures. Elements at the narrow ends of the cycle are large and wedge-shaped. The central area is completely occupied by 2 rows of elements. The shared suture of the rows lies along the long axis of the ellipse. The 2 rows contain a total of 18 elements which become narrow as they meet the inner margin of the rim cycle and thus create 2 rows of depressions. The trace of the proximal shield is noted in 2 distal views. It is composed of about 19 elements and is much smaller than the distal shield—about one-half as long.

Remarks.—This form is definitely composed of 2 shields and is very flat. The only superficially comparable form is the large, Paleogene *Coccolithus macellus* (Bramlette & Sullivan), with lengths (μ) recorded as 7-9, 14, and 9-15, with no rim counts, and with a figure showing 65 rim elements.

Size.—Maximum diameter, 4.3 μ.

Types.—Holotype, UI-H-3150, distal view (Pl. 13, fig. 5). Primary paratype, UI-H-3152, proximal view (Pl. 13, fig. 6). Other paratypes, UI-H-3151, UI-H-3152.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 13, figures 4-6; 4, UI-H-3151, *LW-4*, distal, ×10,800; 5, holotype, UI-H-3150, *LW-4*, distal, ×11,500; 6, UI-H-3152, *LW-4*, proximal, ×13,500.

Family RHABDOSPHAERACEAE Lemmermann, 1908

Organ genus CRETARHABDUS Bramlette & Martini 1964, emend. Bukry

Electron micrographs show that a distinctive rim structure is present in all members of this group. The distal rim, in planar continuity, has 2 essentially radial element cycles. The narrow outer cycle has interelement sutures slightly offset from the interelement sutures of the inner cycle. A single cycle of elements is present in the proximal rim. Forms with single cycle distal rims composed of radial elements, are properly assigned to *Ethmorhabdus* Noël or *Podorhabdus* Noël.

CRETARHABDUS CONICUS Bramlette & Martini

Cretarhabdus conicus Bramlette & Martini, 1964, p. 299, pl. 3, figs. 5-8.——Manivit, 1965, p. 193, pl. 1, fig. 2a-d.——Stover, 1966, p. 140, pl. 1, fig. 19-20, pl. 8, fig. 9.——Gartner, 1968 *(partim)*, p. 21, pl. 1, fig. 11; pl. 3, fig. 5a-c; pl. 6, fig. 3a-c; pl. 11, fig. 12a-c; pl. 20, fig. 8-9; pl. 22, fig. 20-21.

Remarks.—As originally figured in light micrographs, *Cretarhabdus conicus* has a relatively narrow rim and large central area composed of an axial cross and 2 or 3 cycles of perforations. *C. crenulatus* has a broad rim and small central area with only a single cycle of a few so-called perforations. This distinction can be readily applied to electron micrographs. In distal view, the rim is composed of 2 cycles of 22 to 32 elements that are radially aligned. Sutures of the narrow outer cycle are slightly offset from those of the inner cycle. In proximal view, the proximal rim has 23 to 27 elements that are sinistrally imbricated and inclined slightly clockwise. Most specimens have 2 or 3 perforation cycles, but one has 4 cycles. The largest cycle contains 13 to 23 perforations.

Size.—Maximum diameter, 9.2 μ.

Types.—Hypotypes, UI-H-2768 through UI-H-2774, UI-H-3612 through UI-H-3614.

Occurrence.—Localities and samples, *ALB, LW-4, N-100, PB-50, PS-1, S-4, S-11, 42a.* Known range, Albian to Santonian.

Illustrations.—Plate 13, figures 7-12; 7, UI-H-2768, *ALB*, distal, ×10,300; 8, UI-H-2773, *LW-4*, distal, ×8750; 9, UI-H-2774, *LW-4*, distal, ×5700; 10, UI-H-3612, *LW-4*, distal, ×6460; 11, UI-H-3613, *LW-4*, proximal, ×10,100; 12, UI-H-3614, *LW-4*, proximal, ×8550.

CRETARHABDUS CRENULATUS CRENULATUS Bramlette & Martini

Cretarhabdus crenulatus Bramlette & Martini, 1964, p. 300, pl. 2, figs. 21-24.——Manivit, 1965, p. 193, pl. 1, fig. 3a-d.——Reinhardt, 1966, p. 25, pl. 7, fig. 1-2; pl. 14, fig. 2; text-fig. 6a-c.

Cretarhabdus crenulatus Gartner, 1968, *(partim)*, p. 22, pl. 1, fig. 9, pl. 6, fig. 6a-c; pl. 19, fig. 11a-d; pl. 20, fig. 10-11.

Cretarhabdus conicus, Gartner, 1968, *(partim)*, p. 21, pl. 1, fig. 10; pl. 14, fig. 7-9, pl. 16, fig. 12-14; pl. 17, fig. 10a-d; pl. 25, fig. 3-4.

Remarks.—This is by far the most common species of *Cretarhabdus* in the samples studied. The multielement axial crossbars commonly are only slightly developed (Pl. 14, fig. 4). Unlike *C. conicus*, there are no perforations as such, but only interarea voids between the 4 to 15 broad flat radial support struts. These struts arise from the inner surface of the distal rim, creating a crenulate pattern at the margin of the central area. Forms with 1 to 4 struts in each quadrant were observed. In distal view, the rim has 2 cycles of elements, the sutures of these being radial or slightly inclined counterclockwise. Each cycle contains 21 to 27 elements, with slightly sinistral imbrication in the inner cycle and slightly dextral in the narrow outer cycle. In some specimens a small tab occurs at the sinistral margin of the inner cycle elements that overlaps the outer cycle. The outer margin is smooth. In proximal view, the proximal rim is broad and composed of a single cycle of 21 to 26 elements which are slightly arcuate but display no appreciable imbrication or inclination.

Size.—Maximum diameter, 9.6 μ.

Types.—Hypotypes, UI-H-2775 through UI-H-2789, UI-H-3167, UI-H-3615 through UI-H-3618.

Occurrence.—Localities and samples, *ALB, B-8, B-22, C-4, F-14, KG-11, LW-1, LW-2, LW-3, LW-4, N-0, N-100, PB-50, PH-8, PS-1, PSA, PT-6, Q-6, S-1, S-2, S-3, S-4, S-6, S-10, S-11, SF-11, WR, 42a, 42g.* Known range, Turonian-Maastrichtian.

Illustrations.—Plate 14, figures 1-6, 12; 1, UI-H-3615, *WR*, distal, ×7800; 2, UI-H-3616, *LW-2*, distal, ×5810; 3, UI-H-2788, *S-3*, proximal, ×6180; 4, UI-H-3617, *LW-3*, distal, ×8080; 5, UI-H-2789, *LW-4*, distal, ×7600; 6, UI-H-3167, *LW-4*, proximal, ×8080; 12, UI-H-3618, *42a*, distal, ×6650.

CRETARHABDUS CRENULATUS HANSMANII Bukry, n. ssp.

Cretarhabdus conicus, Bramlette & Martini, Gartner, 1968, *(partim)*, p. 21, pl. 3, fig. 6a-d; pl. 4, fig. 9-12.

Cretarhabdus crenulatus Bramlette & Martini, Gartner, 1968, *(partim)*, p. 22, pl. 1, fig. 8.

Description.—The eccentricity of the outline is 1.2 to 1.3. This subspecies has a typical *Cretarhabdus* rim structure. In distal view, a narrow outer cycle of 24 to 28 elements inclines slightly counterclockwise. Neither cycle shows significant imbrication. In proximal view, the smaller proximal rim is composed of a single cycle of 21 to 26 elements with slightly arcuate sutures. The elements imbricate slightly sinistrally and incline slightly clockwise. The central area occupies 48 to 59 percent (55 percent mean) of the coccolith length. In distal view, this area is dominated by support struts of the central stem structure. The 12 struts arising from the distal surface of the inner rim are composed of one or several elements and are indented on either side near the rim. This indentation results in circular to oblong outlines of the through-going interstrut perforations. Taylor Marl specimens have 1 to 3 short lateral processes on either side of these perforations. The bundle of long elements forming the axial cross never extends to the rim. The short-axis bar commonly is reduced to a few perfunctory elements.

Remarks.—This subspecies is separated from *Creta-*

rhabdus crenulatus crenulatus by its 12 wide open rounded perforations formed by indentations in the struts that are not composed of single elements. The minor processes at the perforation sides and the generally larger central area also serve as distinctions. The dimples in the inner-cycle elements occur in various taxa from the Taylor Marl. GARTNER has recorded this form in the Arkadelphia Formation and the Corsicana Marl.

Size.—Maximum diameter, 8.4 μ.

Types.—Holotype, UI-H-2794, distal view (Pl. 14, fig. 8). Primary paratype, UI-H-2790, proximal view (Pl. 14, fig. 9). Other paratypes, UI-H-2790 through UI-H-2793.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian-Maastrichtian.

Illustrations.—Plate 14, figures 7-9; 7, UI-H-2792, *LW-4*, distal, ×10,100; 8, holotype, UI-H-2794, *LW-4*, distal, ×8080; 9, UI-H-2790, *LW-4*, proximal, ×9030.

CRETARHABDUS LORIEI Gartner

Cretarhabdus loriei GARTNER, 1968, p. 21, pl. 24, fig. 9a-d, 10.

Remarks.—This form has been illustrated in light micrographs by GARTNER. Electron micrographs presented here reveal the presence in this form of strong axial crossbars, a long central stem, and a 2-cycle distal rim. These are also characters of *Cretarhabdus conicus*. *C. loriei* is readily distinguished from *C. conicus* by the parallel, diagonal structure in which the central area perforations occur. Four sets of parallel bars or ribs, one set in each quadrant extend to the inner margin of the ring, and make an angle of 45° to 60° with the major axis of the ellipse. Two perforations occur in each diagonal structure. The distal rim is composed of 33, 33, 34 elements in specimens counted. Counts of 35, 33, 32, sinistrally imbricating and radially aligned elements were made on the proximal rim in proximal view. The diagonal central area structures arise on the distal side of the distal rim.

Size.—Maximum diameter, 8.8 μ.

Types.—Hypotypes, UI-H-2795 through UI-H-2801.

Occurrence.—Locality and sample, *LW-4*. Known range, lower Santonian-Campanian.

Illustrations.—Plate 15, figures 1-3; 1, UI-H-2798, *LW-4*, proximal, ×7130; 2, UI-H-2797, *LW-4*, proximal, ×6650; 3, UI-H-2801, *LW-4*, distal, ×6180.

CRETARHABDUS MULTICAVUS Bukry, n. sp.

Description.—The elliptical outline of the distal shield has eccentricity 1.2 to 1.4. In distal view, the rim is composed of 2 cycles of 18 to 26 (24 mean) elements that incline slightly counterclockwise. Element sutures in each cycle are offset. The trace of a smaller proximal rim is noted, its inner margin with a smooth border around the slightly recessed area in distal view. A minor cycle of 21 or 22 dextrally imbricated elements forms the periphery of the central area. The dominant features in this area, however, are axial ridges and perforations within quadrants outlined by the ridges. Each quadrant contains 2 or 3 perforations or depressions and each is outlined by ridges formed by opposing elements meeting along a median suture. No evidence of any central stem structure is found. The ends of the long ridge curve dextrally at the margin of the central area in distal view.

Remarks.—The distal-shield rim structure is of *Cretarhabdus* type, but no stem structure is seen.

Size.—Maximum diameter, 6.9 μ.

Types.—Holotype, UI-H-3166, distal view (Pl. 14, fig. 11). Paratypes, UI-H-3164, UI-H-3165, UI-H-3168.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *B-8*, *LW-3*, *LW-4*. Known range, Campanian.

Illustrations.—Plate 14, figures 10-11; 10, UI-H-3165, *B-8*, distal, ×7130; 11, holotype, UI-H-3166, *LW-4*, distal, ×10,800.

CRETARHABDUS SCHIZOBRACHIATUS (Gartner) Bukry, n. comb.

Vekshinella schizobrachiata GARTNER, 1968, p. 31, pl. 13, fig. 10-11; pl. 20, fig. 5.

Remarks.—This form has a bilamellar rim and therefore is not attributable to *Vekshinella*. Diagonal support struts of the axial cross and the 2-cycle distal rim indicate that it should be classified as a species of *Cretarhabdus*. The original description mentions 40 to 50 rim elements. Specimens from the samples studied by me show 24 to 31 elements in the inner and outer cycles of the distal rim and 24 to 30 elements in the proximal rim cycle. Sutures are essentially radial. The splitting-off of 2 bars as the crossbars near the rim is only apparent, for structurally they do not necessarily split.

Size.—Maximum diameter, 6.7 μ.

Types.—Hypotypes, UI-H-2802 through UI-H-2807.

Occurrence.—Localities and samples, *ALB*, *B-8*, *LW-3*, *LW-4*, *PT-6*, *S-1*, *S-4*, *42a*. Known range, Albian-Campanian.

Illustrations.—Plate 15, figures 4-6; 4, UI-H-2806, *LW-4*, distal, ×8750; 5, UI-H-2802, *ALB*, proximal, ×9370; 6, UI-H-2803, *42a*, distal, ×8340.

CRETARHABDUS UNICORNIS Stover

Cretarhabdus unicornis STOVER, 1966, p. 140, pl. 5, fig. 15-16; pl. 9, fig. 15.

Remarks.—Electron micrographs show that each of the 4 circular perforations is surrounded by a cycle of 10 elements. Bundles of long narrow elements form the X-shaped crossbars that are symmetric about the long axis of the ellipse. The distal rims show the typical 2 cycles of elements lying in the same plane. The outer one is proportionally wider in *Cretarhabdus unicornis* than in other species. Imbrication is slight in each cycle, but dextral in the outer and sinistral in the inner cycle. Each is composed of 33 to 39 elements. The inner cycle sutures are radially oriented, whereas the outer sutures incline very slightly counterclockwise. The sinistral side of each inner cycle element has a tab of variable length that overlaps the outer cycle. The solid, slender, central stem is not noticeably spiraled.

Size.—Maximum diameter, 11.5 μ.

Types.—Hypotypes, UI-H-2808 through UI-H-2810.

Occurrence.—Localities and samples, *LW-2, Q-6, Q-7, S-1, S-2, S-3, S-11, SF-11.* Known range, Albian-Santonian.

Illustrations.—Plate 15, figures 7-9; 7, UI-H-2809, *S-2,* distal, ×5180; 8, UI-H-2810, *S-3,* distal, ×4850; 9, UI-H-2808, *S-11,* distal, ×5810.

Organ genus ETHMORHABDUS Noël, 1965

ETHMORHABDUS CAMARATUS Bukry, n. sp.

Description.—Eccentricities of the smooth elliptical outline are 1.2 to 1.3. The distal rim is a single, broad cycle of 22 to 30 (27 mean) straight-sutured elements that are radial or inclined very slightly counterclockwise. In proximal view, the proximal rim is a single cycle of 23 essentially radial elements with slightly arcuate sutures. The central area is composed of a monolamellar, perforated cone and crossbar-stem combination that is arched distally. Small cycles of 4 or 5 elements outline 9 to 18 polygonal openings. The interlocked cycles make up the central area. The cycle elements are of such a thickness that the perforations are recessed in both proximal and distal views. The entire central area occupies 50 to 61 percent (57 percent mean) of the total shield length. A narrow X-shaped crossbar, made of a few narrow elements, is asymmetric to the ellipse axes. The long bar may curve very slightly sinistrally as it nears the rim, but is usually straight. At the center is a narrow, solid stem composed of 4 or 5 elongate elements.

Remarks.—The perforation structures are similar to those of *Nephrolithus* species, which have different rims, however, and lack crossbars. No other species of *Ethmorhabdus* has this type of central area.

Size.—Maximum diameter, 10 μ.

Types.—Holotype, UI-H-2816, distal view (Pl. 15, fig. 11). Primary paratype, UI-H-2815, proximal view (Pl. 15, fig. 12). Other paratypes: UI-H-2811 through UI-H-2815, UI-H-2817.

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Localities and samples, *B-8, B-22, LW-4.* Known range, Campanian.

Illustrations.—Plate 15, figures 10-12; 10, UI-H-2817, *LW-4,* distal, ×8750; 11, holotype, UI-H-2816, *B-8,* distal, ×5490; 12, UI-H-2815, *B-8,* proximal, ×6460.

Organ genus PODORHABDUS Noël, 1965

PODORHABDUS DIETZMANNI (Reinhardt), Bukry, n. comb.

Ahmuellerella dietzmanni Reinhardt, 1965, p. 30, pl. 1, fig. 1, text-fig. 1.

Cretarhabdus dietzmanni (Reinhardt), Reinhardt, 1966, p. 27, pl. 22, fig. 1.

Prediscosphaera? orbiculofenestra Gartner, 1968, p. 21, pl. 25, fig. 23-25.

Remarks.—Instead of being elliptical, this form commonly has 2 long approximately parallel sides. Eccentricities recorded are all 1.4. In distal view 2 cycles form the narrow rim. The wider, outer cycle slopes adcentrally, whereas the narrow inner cycle slopes abcentrally. Rectangular elements (35 to 48) with slight dextral imbrication and slight clockwise inclination compose the outer cycle in distal view. The inner cycle of 34 to 48 elements imbricates very slightly sinistrally and is inclined very slightly clockwise. A large central area is dominated by an apron of many small elements that rises distally from the rim to form a large central hollow stem. Elements in the stem are spiraled by slight dextral imbrication. The apron is pierced by 4 circular perforations with small rims of elements forming their margins. The perforations are always oriented symmetric with the long and short axes of the ellipse. The interarea along the short axis of the ellipse is at least twice as wide as the interarea along the long axis of the ellipse. The symmetry and shape of the central-area structures are very distinctive.

Size.—Maximum diameter, 9.6 μ.

Types.—Hypotypes, UI-H-2818 through UI-H-2821.

Occurrence.—Localities and samples, *B-8, LW-3, LW-4, N-100, PB-50, PH-8, S-3, S-4, S-6, WR.* Known range, Cenomanian-Campanian.

Illustrations.—Plate 16, figures 1-3; 1, UI-H-2818, *B-8,* distal, ×4850; 2, UI-H-2819, *LW-4,* distal, ×7130; 3, UI-H-2820, *PB-50,* distal, ×7600.

PODORHABDUS GRANULATUS (Reinhardt), Bukry, n. comb.

Ahmuellerella? granulata Reinhardt, 1965, p. 39, pl. 3, fig. 2.

Cretarhabdus? granulatus (Reinhardt), Reinhardt, 1966, p. 27, pl. 8, fig. 1.

Remarks.—This elliptical coccolith with bilamellar rim has an eccentricity of 1.2 to 1.3. In distal view, 2 cycles of rectangular elements are seen small, sinistrally imbricated, essentially radial, and equal or fewer in number in the inner cycle than in the outer one, which is composed of 22 to 35 radially oriented elements that form a smooth outer margin. The open central area is spanned by a large X-shaped crossbar that rises distally to support a large, hollow stem. The bars are symmetric about the long axis of the ellipse. Crossbars are composed of a multitude of very small elements aligned with the crossbar outlines. At the base of the stem these elements begin to spiral by dextral imbrication and continue spirally to form the central stem. The small, proximal rim cycle has 26 radial elements in the proximal views observed. In the original description, Reinhardt noted 60 elements in the outer rim. The only figure presented (specimen from a Maastrichtian deposit) shows only 38 elements, however.

Size.—Maximum diameter, 9.8 μ.

Types.—Hypotypes, UI-H-2822 through UI-H-2825.

Occurrence.—Localities and samples, *LW-4, PB-50, S-1, S-2, S-3, WR.* Known range, Santonian-Maastrichtian.

Illustrations.—Plate 16, figures 4-6; 4, UI-H-2822, *PB-50,* distal, ×7600; 5, UI-H-2824, *S-1,* proximal, ×8080; 6, UI-H-2825, *S-1,* distal, ×9440.

PODORHABDUS QUADRIPERFORATUS Bukry, n. sp.

Description.—The distal shield is distinctly larger than the proximal shield. Each is elliptical, with eccentricities of 1.3. In distal view, a broad outer rim cycle, narrow inner cycle, and rather large central opening spanned by axial crossbars are seen. A short hollow central stem occurs at the crossbar center. The 17 to 25 (20 mean) elements of the outer cycle imbricate slightly dextrally and incline slightly counterclockwise. The inner cycle is made of 18 to 26 (21 mean) square-outlined elements with radial sutures and no significant imbrication. Each crossbar arm is constructed of 2 lateral rows of small elements. In proximal view the outer cycles of both the proximal and distal shields are slightly imbricated dextrally and have essentially radial sutures. The inner cycle of the proximal rim duplicates the inner cycle of the distal rim. The most distinctive feature of the proximal shield occurs only in well-preserved specimens. A reticulate plate covers the base of each of the 4 central openings. The 4 plates are generally broken, but may contain approximately 12 small pores when intact.

Remarks.—Specimens retaining portions of the reticulate plates were encountered only in the lower Taylor Marl.

Size.—Maximum diameter, 12 μ.

Types.—Holotype, UI-H-2887, proximal view (Pl. 16, fig. 8). Primary paratype, UI-H-2884, distal view (Pl. 16, fig. 11). Other paratypes, UI-H-2883 through UI-H-2886, UI-H-2888, UI-H-2889.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-3, LW-4, PB-50, N-100, PSA, Q-3, S-3, S-4, WR, 42a.* Known range, Santonian-Campanian.

Illustrations.—Plate 16, figures 8-11; 8, holotype, UI-H-2887, *LW-4,* proximal, ×9440; 9, UI-H-2889, *LW-4,* proximal, ×8750; 10, UI-H-2883, *WR,* proximal, ×9440; 11, UI-H-2884, *LW-3,* distal, ×9980.

PODORHABDUS REINHARDTII Bukry, n. sp.

Description.—This form possesses the general characters of *Podorhabdus dietzmanni,* with an outer rim composed of about 56 radial elements. Eccentricity of the rim outline is 1.5. There are 8 large, round, rimmed perforations in the central area symmetrical about the long and short axes of the ellipse.

Remarks.—Although the center of this specimen is broken, the structure of the coccolith is comparable to that of *Podorhabdus dietzmanni.* It is distinguished from *P. dietzmanni* by the presence of 8 perforations instead of 4 and by the resulting elongation and enlargement required to accommodate these perforations. The specimen is from a sample in which *P. dietzmanni* is also present.

Size.—Maximum diameter, 11.5 μ.

Type.—Holotype, UI-H-2826 (Pl. 16, fig. 7).

Occurrence.—Type stratigraphic source, lower middle Austin Chalk. Type locality, Stream at Presbyterian Hospital, Dallas, Texas. Locality and sample, *PH-8.* Known range, lower Santonian.

Illustrations.—Plate 16, figure 7, holotype, UI-H-2826, *PH-8,* distal, ×4850.

Organ genus PREDISCOSPHAERA Vekshina, 1959

PREDISCOPHAERA CRETACEA CRETACEA (Arkhangelsky) Gartner

Prediscosphaera cretacea (Arkhangelsky), GARTNER, 1968, p. 21, pl. 2, fig. 10-14; pl. 3, fig. 8, etc.

Deflandrius intercisus MANIVIT, 1965, p. 193, pl. 1, fig. 7a-d.——STOVER, 1966, p. 142, pl. 6, figs. 1-5.

Deflandrius cretaceus cretaceus REINHARDT, 1966, *(partim),* p. 35, pl. 15, fig. 4.

Deflandrius cretaceus intercisus REINHARDT, 1966, p. 35, pl. 22, fig. 2; pl. 19, fig. 3; text-fig. 20.

For complete pre-1965 synonomy see GARTNER, 1968, p. 21.

Remarks.—This species is a universal dominant in Upper Cretaceous coccolith samples. The taxonomic problems of the form were described by GARTNER. On the basis of 250 new electron micrographs, some additional structural information can be provided. The elliptical to circular outline of the 16-element rim has eccentricities of 1.0 to 1.3 (1.2 mean). The elements in the outer cycle of the distal rim have an entirely unique shape. On the sinistral margin of each element is an "arrowhead-shaped" or "pipe-bowl-shaped" tab that overlaps or penetrates the dextral margin of the adjacent element (Pl. 17, fig. 1). Though the size of the tab varies, it occurs on every specimen. The central area is lined with a very narrow cycle of about 16 sinistrally imbricated elements. The central area occupies 41 to 63 percent (55 percent mean) of the coccolith length. The orthogonal X-shaped crossbar structure is symmetric about the coccolith axes. The central stem is square in section. While the crossbar structure arises from the rim at the top of central area, a second crossbar set rotated slightly sinistrally occurs below the first set that arises from the top of the proximal shield. In proximal view the proximal rim is seen to be composed of 16 radial elements with a notch developed in each side of each element at about 0.7 of the distance into the central area. A great deal of variety characterizes proportions of the stem structure. Two new subspecies are proposed for forms showing distinctive variations.

Size.—Maximum diameter, 6 μ; maximum height, 9.4 μ.

Types.—Hypotypes, UI-H-2827 through UI-H-2846, UI-H-3619.

Occurrence.—Localities and samples, *B-8, B-22, C-4, F-14, KG-11, LW-1, LW-2, LW-3, LW-4, N-11+8, N-100, PB-50, PH-8, PS-1, PSA, PT-6, Q-6, S-1, S-3, S-4, S-10, S-11, SF-11, WR, 42a, 42g.* Known range, Albian-Maastrichtian.

Illustrations.—Plate 16, figure 12; Plate 17, figures 1-6.——Pl. 16, fig. 12, UI-H-2829, *S-4,* distal, ×9440.——Pl. 17, fig. 1-6; 1, UI-H-2834, *LW-4,* distal, ×10,100; 2, UI-H-2841, *S-1,* proximal, ×7130; 3, UI-H-2846, *LW-4,* distal, ×10,800; 4, UI-H-3619, *LW-4,* side, ×9440; 5, UI-H-2830, *B-8,* side, ×6650; 6, UI-H-2831, *B-8,* side, ×5490.

PREDISCOSPHAERA CRETACEA LATA Bukry, n. ssp.

Description.—This elliptical subspecies has eccentricity of 1.1 to 1.4 (1.2 mean). While the rim structure is identical to *Prediscosphaera cretacea* (ARKHANGELSKY), the central area is distinctly modified. The slightly recessed, usually narrow cycle that lines the central area in other species of *Prediscosphaera* is greatly widened in this form. It is more than half as wide as the outer rim, which has slight sinistral imbrication; the widened inner cycle is dextrally imbricated. In some specimens the elements of the inner cycle have tabs like those of the outer cycle, except that the sense of penetration is reversed. Two sets of crossbars are seen, the larger set rising from the inner margin of the outer cycle. Distinctly shorter and sinistrally rotated, the second set rises from the inner margin of the inner cycle. The area within the outer margin of the inner cycle occupies 54 to 63 percent of the coccolith length. The actual open area within the inner margin of the inner cycle occupies only 29 to 43 percent (38 percent mean).

Remarks.—The broad inner rim distinguishes this subspecies, which has been observed only in Campanian and Maastrichtian samples from Europe.

Size.—Maximum diameter, 8.3 μ.

Types.—Holotype, UI-H-2851, distal view (Pl. 17, fig. 8). Paratypes, UI-H-2847 through UI-H-2850.

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Localities and samples, *B-8, B-22, KG-11?*. Known range, Campanian-Maastrichtian.

Illustrations.—Plate 17, figures 7-9; 7, UI-H-2850, *B-8*, distal, ×8550; 8, holotype, UI-H-2851, *B-8*, distal, ×7130; 9, UI-H-2848, *B-22*, distal, ×7300.

PREDISCOSPHAERA CRETACEA PONTICULA Bukry, n. ssp.

Description.—This circular subspecies has eccentricity of 1.0 or 1.1. Distal and proximal rim structures are identical with those of *Prediscosphaera cretacea* (ARKHANGELSKY). The proximal rim is about the same in size as the distal rim. The central area, with eccentricity 1.0 to 1.3 (1.1 mean), occupies 34 to 45 percent of the longest coccolith axis. Four single crystallite elements extend from the margin of the central area (about the halfway point along the margin between the major crossbar junctures) to the inner end of the crossbars. Though not in contact with each other, these slender auxillary elements are perpendicular to the adjacent 2. They make an angle of 60° to 70° with the major crossbar that they join.

Remarks.—The proportionally broader rim, more circular outline, and 4 slender auxillary bars readily distinguish this subspecies. Although observed only from the Austin Chalk samples, SUSUMU HONJO has informed me of the presence of this variety in the Niobrara Formation.

Size.—Maximum diameter, 7.8 μ.

Types.—Holotype, UI-H-2858, proximal view (Pl. 17, fig. 11). Primary paratype, UI-H-2857, distal view (Pl. 17, fig. 10). Other paratypes, UI-H-2852 through UI-H-2857, UI-H-2859.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, South Dallas County, Texas. Localities and samples, *PB-50, PSA, Q-5, S-1, S-2, S-3, S-10, S-11*. Known range, Santonian.

Illustrations.—Plate 17, figures 10-12; 10, UI-H-2857, *S-1*, distal, ×7130; 11, holotype, UI-H-2858, *S-1*, proximal, ×7130; 12, UI-H-2853, *S-11*, distal, ×6650.

PREDISCOSPHAERA GERMANICA Bukry, n. sp.

Description.—The outline of the 16-element rim cycle has eccentricities of 1.2 to 1.4. The sutures of this outer rim cycle are radially oriented, and the elements imbricate slightly dextrally in some specimens. A very distinctive inner cycle of 10 to 15 (14 mean) elements lines the central area and has rodlike processes extending onto the outer cycle. The distal side of each element has a long extension that apparently imbricates dextrally. A serrate outline strongly inclined clockwise results. Actually, the entire element is part of a sinistrally imbricated cycle. The central area occupies 49 to 67 percent (55 percent mean) of the coccolith length. A crossbar aligned with the long and short axes of the coccolith supports a slender 4-element central stem. The crossbars are composed of only 1 or 2 rodlike elements. Juncture of the crossbars with the inner cycle processes commonly results in the formation of a swastika figure. Although no proximal views are yet recognized, the trace of a slightly smaller proximal cycle can be seen in several specimens. This proximal shield contains 16 radial rim elements.

Remarks.—This species is distinguished from *Prediscosphaera cretacea* (ARKHANGELSKY) by absence of tabs in the outer rim elements, by processes of the inner cycle, and by having crossbars aligned with the long and short coccolith axes. It is distinguished from *P. spinosa* (BRAMLETTE & MARTINI) by having a smaller central area and by its distinctive serrate inner cycle of elements that overlaps the outer cycle.

Size.—Maximum diameter, 7 μ.

Types.—Holotype, UI-H-2861, distal view (Pl. 18, fig. 3. Paratypes, UI-H-2860, UI-H-2862 through UI-H-2864.

Occurrence.—Type stratigraphic source, Aachen marl. Type locality, Aachen, Germany. Localities and samples, *B-8, B-22*. Known range, Campanian.

Illustrations.—Plate 18, figures 1-3; 1, UI-H-2864, *B-8*, distal, ×10,100; 2, UI-H-2863, *B-8*, distal, ×12,100; 3, holotype, UI-H-2861, *B-22*, distal, ×12,500.

PREDISCOSPHAERA HONJOI Bukry, n. sp.

Coccolithus sp. aff. *C. helis* Stradner, GARTNER, 1968, p. 18, pl. 4, fig. 8.

Description.—This small elliptical species has 16 elements in both distal and proximal rims. The eccentricity of the outline is 1.2 to 1.4. In distal view, the rim cycle elements are straight-margined and radially oriented. A narrow cycle of 10 to 12 elements lines the small central area which occupies only 30 to 41 percent of the coccolith length. In proximal view the proximal rim cycle elements have the same notching of their sutures that is observed in other *Prediscosphaera* species. The inner cycle can be clearly seen in this view. The small, simple crossbars are aligned with the long and short axes of the coccolith. The slender, square cross section central stem is usually broken away.

Remarks.—The combination of elliptical outline, small central area, and unmodified inner cycle distinguish this species from others included in *Prediscosphaera*. GARTNER's specimen was from the Corsicana Marl of Texas.

Size.—Maximum diameter, 4.8 μ.

Types.—Holotype, UI-H-2870, distal view (Pl. 18, fig. 6). Primary paratype, UI-H-2872, proximal view (Pl. 18, fig. 5). Other paratypes, UI-H-2865 through UI-H-2868, UI-H-2870 through UI-H-2872.

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Localities and samples, *B-8, B-22, N-100*. Known range, Santonian-Maastrichtian.

Illustrations.—Plate 18, figures 4-6; 4, UI-H-2865, *B-22*, distal, ×14,400; 5, UI-H-2872, *B-8*, proximal, ×13,500; 6, holotype, UI-H-2870, *B-8*, distal, ×10,900.

PREDISCOSPHAERA SPINOSA (Bramlette & Martini), Gartner

Deflandrius spinosus BRAMLETTE & MARTINI, 1964, p. 301, pl. 2, fig. 17-20.

Eiffellithus cretaceus cretaceus REINHARDT, 1965, p. 35, pl. 2, fig. 4; text-fig. 3.

Prediscosphaera spinosa GARTNER, 1968, p. 20, pl. 1, fig. 15-16; pl. 3, fig. 9a-b, 10a-b; pl. 5, fig. 7-9; pl. 6, fig. 16a-d; pl. 11, fig. 17a-c.

Remarks.—The elliptical outline of this form has eccentricities of 1.1 to 1.4 (1.3 mean). The distal rim is composed of 16 equal-sized, wedge-shaped elements that imbricate very slightly dextrally. A narrow inner rim cycle of about 16 elements lines the central area. The largest face of these elements is adcentrally sloping. Though the actual elements imbricate sinistrally, the narrow distal faces are slanted to create apparent dextral imbrication (this same effect is seen in the related form, *Prediscosphaera germanica* BUKRY, n. sp.). The central area occupies 46 to 58 percent of the coccolith length. Narrow crossbars of a few rod elements are aligned to the long and short axes of the coccolith. There is a slender stem of 4 rod elements. In proximal view, 2 rim cycles are observed in the proximal shield. These cycles both contain about 16 elements. The margins of the outer-cycle elements are radial or slightly clockwise inclined; the inner elements are radial or slightly counterclockwise inclined. The central area crossbars are attached to the inner margins of both proximal and distal rims. Instead of overlapping the outer rim cycle, as in *P. germanica* BUKRY, n. sp., the inner-cycle elements are slightly recessed below the outer cycle. There are indications of the *P. germanica* serrate cycle here, such that development from *P. spinosa* is probable. *P. cretacea* has outer rim tabs and an X-shaped crossbar which distinguish it from *P. spinosa*.

Size.—Maximum diameter, 6.5 μ.

Types.—Hypotypes, UI-H-2873 through UI-H-2882, UI-H-3620.

Occurrence.—Localities and samples, *B-8, B-22, LW-1, LW-2, LW-4, N-0, N-100, PT-6, Q-6, S-2, S-3, S-10, S-11, SF-10, 42a, 42g*. Known range, Santonian-Maastrichtian.

Illustrations.—Plate 18, figures 7-9; 7, UI-H-3620, *S-3*, distal, ×10,100; 8, UI-H-2878, *LW-4*, distal, ×10,100; 9, UI-H-2881, *LW-4*, proximal, ×9030.

Family STEPHANOLITHIONACEAE Bukry, n. fam.

This varied group is composed of tall and short prismatic and cylindrical forms that may be closed or open. The walls are usually a single cycle of a small number of elements. Forms with open centers are commonly bridged by crossbar structures supporting short, solid stems. Both open or closed forms may have a few spines or projections extending from the external surface.

Organ genus COROLLITHION Stradner, 1961

COROLLITHION ELLIPTICUM Bukry, n. sp.

Description.—This small species has an elliptical eccentricity of 1.3 to 1.5. The narrow rim is composed of 17 and 20 radial elements in the 2 specimens counted. In one of the distal views, a secondary cycle of 22 radially arranged elements is observed. An open central area and an asterisk-shaped crossbar set occupies 62 to 86 percent of the length of the coccolith. One bar is aligned with the short axis of the ellipse; the other 2 bars are symmetrical about the long axis. Because of the elliptical outline, the 2 interarea openings at ends of the ellipse are distinctly larger than the 4 openings next to the short axis. One of the diagonal bar-sets is regularly offset at the center.

Remarks.—A comparable form is *Discolithus geometricus* GORKA. Distinction is made on the disposition of the crossbars and the resulting interarea openings. *D. geometricus* has 2 small openings at the ends of the ellipse caused by both diagonal crossbar-sets being offset. In contrast, these openings are large in *Corollithion ellipticum*. There is no evidence of a secondary rim cycle or any other structure in the diagrammatic figure of *D. geometricus*.

Size.—Maximum diameter, 4.4 μ.

Types.—Holotype, UI-H-3561, proximal view (pl. 18, fig. 10). Paratypes, UI-H-3562 through UI-H-3564.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 18, figures 10-11; 10, holotype, UI-H-3561, *LW-4*, proximal, ×14,300; 11, UI-H-3564, *LW-4*, proximal, ×20,800.

COROLLITHION EXIGUUM Stradner

Corollithion exiguum STRADNER, 1961, p. 83, text-fig. 58-61.——STRADNER, 1963, p. 178, pl. 1, fig. 12.——BRAMLETTE & MARTINI, 1964, p. 308, pl. 5, fig. 8-9.

Corollithion exiguum, MARESCH, 1966, p. 381, pl. 3, fig. 4.——

REINHARDT, 1966, p. 41, pl. 19, fig. 5.——GARTNER, 1968, p. 35, pl. 10, fig. 26.

Stephanolithion sp. aff. *S. laffittei* Noël, GARTNER, 1968, p. 35, pl. 5, fig. 14; pl. 22, fig. 18.

Remarks.—Crossbar and rim structures of *Corollithion exiguum* are similar to those of *C. signum* STRADNER. *C. exiguum* usually has 2 short opposite sides in the hexagonal frame, which is different from *C. signum* which has 4 short limbs. *C. exiguum* has a small central stem built of 6 to 10 rods, and an apparent development of peripheral processes at the corners of the frame (the outer rim cycle is missing when these processes are present). Coalescence of elements makes outer rim counts difficult. Minimum counts of 13 to 20 were made; only dextral imbrications were observed.

Size.—Maximum diameter, 4.6 μ.

Types.—Hypotypes, UI-H-3565 through UI-H-3570.

Occurrence.—Localities and samples, *B-8, B-22, LW-4, N-100, PSA, Q-4, Q-6, S-1, S-3, S-4, S-10, S-11, WR, 42a.* Known range, upper Turonian-Maastrichtian.

Illustrations.—Plate 18, figure 12; Plate 19, figure 1.——Pl. 18, fig. 12, UI-H-3568, *LW-4*, distal, ×11,500.——Pl. 19, fig. 1, UI-H-3567, *S-1*, distal, ×9500.

COROLLITHION RHOMBICUM (Stradner & Adamiker), Bukry, n. comb.

Zygolithus rhombicus STRADNER & ADAMIKER, 1966, p. 339, pl. 2, fig. 1, text-fig. 5-7.

Remarks.—This small species has a well-defined to rounded rhombic outline. The open central area is filled with a unique set of 8 bars and a central stem. Small angles of the rhombic frame measure from 40° to 73° (56° mean). The slightly scalloped rim is constructed of 24 to 44 (31 mean) thick, radially arranged elements in an outer cycle. On some specimens a thin inner cycle of elements appears to line the central area. The inside and outside of the thin rim slopes adcentrally in distal view. The crossbar structure may be described as a combination of a central "X" and "Y" opening toward each small angle of the frame. The tail of the "Y" and center of the "X" meet to support a short stem at the center of the central area. Thus, each side of the rhombic frame has 2 short bars perpendicular to it. The bars extend to a central bar aligned with the long diagonal of the rhomb. Structurally, the bars are built of only a few, lath-shaped elements. The central stem is a bundle of 5 to 10 rods. A number of variations included in this species are represented by 1) 12 specimens from the Austin Chalk and Niobrara Formation, all with distinctly larger small angles of the rhombic frame. The mean angle of the group is 67°, in contrast to 52° for the Aachen marl and 51° for the lower Taylor Marl. Therefore, it seems likely that a sample of specimens from the Santonian may be distinguished from Campanian samples by this criterion. It would be interesting, however, to know how this property varies in modern Calciosolenidae that also produce coccoliths with rhombic frames. 2) Nine specimens from the lower Taylor Marl all show an asymmetrical displacement of the central stem and associated bars to one end of the central bar. The displacement occurs in no other specimens. 3) A sample from the Aachen marl includes 13 of 21 specimens which have a short crossbar parallel to the short diagonal right at small-angle ends of the frame. This accessory bar does not occur elsewhere.

Size.—Maximum diameter, 6 μ.

Types.—Hypotypes, UI-H-3571 through UI-H-3578.

Occurrence.—Localities and samples, *B-8, B-22, LW-4, N-100, PH-8, PSA, Q-5, Q-6, S-1, WR, 42g.* Known range, Albian-Campanian.

Illustrations.—Plate 19, figures 2-4; 2, UI-H-3574, *LW-4*, distal, ×13,500; 3, UI-H-3575, *LW-4*, proximal, ×14,200; 4, UI-H-3573, *B-22*, distal, ×13,500.

COROLLITHION SIGNUM Stradner

Corollithion signum STRADNER, 1963, p. 177, pl. 1, fig. 13.——MARESCH, 1966, p. 381, pl. 3, fig. 3.

Corollithion sp. MANIVIT, 1965, p. 194, pl. 1, fig. 6a-b.

Remarks.—STRADNER's description of this species is: "Coccoliths with hexagonal outline: the large central opening is filled out with a straight cross (Lat., *cum signo crucis*)." A small generalized diagram of the species was presented. On the basis of 46 electron micrographs, additional structural details can be described. In distal view, the outer-rim cycle is hexagonal to round, with 2 parallel sides and 2 rounded ends being the most frequent outline. The rim cycle is composed of 23 to 27 (24 mean) elements. Usually a more hexagonal inner cycle of 8 to 11 dextrally imbricating and adcentrally sloping elements form a frame for the central area cross. The cross is not so symmetrically placed as STRADNER's sketch implies. Its long bar is rotated dextrally away from the position of a symmetric crossbar in distal view (sinistrally in proximal view). Conversely, the short bar is rotated slightly sinistrally in distal view. The ends of the cross flare asymmetrically with the larger extension projecting in a sinistral direction. The long bar of the cross is narrower than the short one. In proximal view, the crossbars are seen to be composed of double rows of elements arched distally. Some proximal views show a small secondary cycle of about 21 radially arranged elements. No central stem occurs. Proportions of cross, rim, and central area vary.

Size.—Maximum diameter, 4.9 μ.

Types.—Hypotypes, UI-H-3589 through UI-H-3595.

Occurrence.—Localities and samples, *ALB, B-8, LW-1, LW-2, LW-3, LW-4, N-11+8, N-100, PB-50, PH-8, PSA, PT-6, S-1, S-2, S-3, S-4, S-11, WR, 42a.* Known range, Albian-Campanian.

Illustrations.—Plate 19, figures 5-8; 5, UI-H-3595, *LW-4*, distal, ×12,100; 6, UI-H-3591, *LW-4*, proximal, ×12,800; 7, UI-H-3594, *LW-1*, distal, ×10,100; 8, UI-H-3593, *LW-1*, proximal, ×10,100.

Organ genus CYLINDRALITHUS Bramlette & Martini, 1964

CYLINDRALITHUS ASYMMETRICUS Bukry, n. sp.

Description.—The walls of this double-flaring cylindrical form are fluted, producing a dentate margin in proximal and distal views. The central opening is commonly elliptical, with eccentricities of 1.1 to 1.3. There are 15 to 24 (20 mean) columnar elements in the wall cycle. In proximal view a small element is seen at the inner end of each wall-element suture. The X-shaped crossbar is slender and makes small angles (20° to 34°) with the short axis of the elliptical central area.

Remarks.—This form is distinguished from *Cylindralithus coronatus* Bukry, n. sp., in having a slender X-shaped crossbar that is set in an elliptical opening. *C. biarcus* Bukry, n. sp., differs in having 2 thick arcs which form the crossbar.

Size.—Maximum diameter, 5.9 μ.

Types.—Holotype, UI-H-2946, proximal view (Pl. 19, fig. 10). Primary paratype, UI-H-2953, distal view (Pl. 19, fig. 11). Other paratypes, UI-H-2947 through UI-H-2953.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-1, LW-4, N-100, Q-2, S-1, S-3, S-6, S-10, S-11, 42g.* Known range, Santonian-Campanian.

Illustrations.—Plate 19, figures 9-12; 9, UI-H-2949, *S-6,* proximal, ×11,500; 10, holotype, UI-H-2946, *LW-4,* proximal, ×10,100; 11, UI-H-2953, *LW-4,* distal, ×11,500. UI-H-2951, *42g,* proximal, ×9440.

CYLINDRALITHUS BIARCUS Bukry, n. sp.

Description.—This form is approximately circular in distal and proximal views. The 20 to 28 columnar elements that compose the cylindrical wall flare out toward the distal and proximal openings. The latter has 2 arcuate crossbars tangent at the center of the opening. This structure results in 2 large and 2 small perforations. The crossbars are constructed of 10 to 20 block elements. Maximum diameter of the proximal opening represents 42 to 53 percent of the greatest diameter of the fluted outer wall.

Remarks.—The only other species of *Cylindralithus* with a large crossbar, *C. coronatus* Bukry, n. sp., has 4 equal bars meeting at about 90° to form the cross.

Size.—Maximum diameter, 7.2 μ.

Types.—Holotype, UI-H-2968, proximal view (Pl. 20, fig. 2). Primary paratype, UI-H-2969, distal view (Pl. 20, fig. 3). Other paratypes, UI-H-2967 and UI-H-2969 through UI-H-2971.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and sample, *LW-4, WR.* Known range, Santonian-Campanian.

Illustrations.—Plate 20, figures 1-3; 1, UI-H-2967, *WR,* proximal, ×5700; 2, holotype, UI-H-2968, *LW-4,* proximal, ×8080; 3, UI-H-2969, *LW-4,* distal, ×7600.

CYLINDRALITHUS CORONATUS Bukry, n. sp.

Zygolithus maltanensis (Gorka), Stradner, 1963, p. 178, pl. 2, fig. 10.

Cylindralithus achylosus (Stover) Gartner, 1968, p. 46, pl. 21, fig. 10a-c?; pl. 22, fig. 23.

Description.—The high wall of this species is a tapering cylinder composed of 20 to 24 elements. The wall cycle is ribbed or serrate and has no secondary or lining cycle of elements. At both large and small ends of the cylinder the wall flares out. A 4-bar cross structure is present in the smaller proximal end of the cylinder. The broad complexly structured bars usually meet at 90° angles but can vary to 67°. In distal view, the crossbars show a surface of lath elements aligned with the crossbar direction. In proximal view, however, each bar shows a surface of 2 rows of intercalated triangular elements.

Remarks.—Similar differences in structural pattern between distal and proximal views of crossbars are seen in other Cretaceous genera. This species is distinguished from *Cylindralithus achylosus* (Stover) in having a much higher cylinder wall which is ribbed or serrate in well-preserved forms, in having far fewer wall elements than the approximately 36 shown in Stover's illustrations, and in lacking a lining cycle. The new species is also distinguished from *C. maltanensis* (Gorka) in having parallel-margined crossbars instead of maltese crossbars.

Size.—Maximum diameter, 6.7 μ.

Types.—Holotype, UI-H-2959 (pl. 20, fig. 4). Primary paratype, UI-H-2956 (pl. 20, fig. 6). Other paratypes, UI-H-2954 through UI-H-2958 and UI-H-2960 through UI-H-2962.

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Shook Avenue at White Rock Road, Dallas, Texas. Localities and samples, *LW-4, PH-8, PS-1, PSA, S-1, S-4, S-10, S-11, WR.* Known range, Santonian-Campanian.

Illustrations.—Plate 20, figures 4-6; 4, holotype, UI-H-2959, *WR,* proximal, ×8550; 5, UI-H-2958, *S-10,* proximal, ×6460; 6, UI-H-2956, *LW-4,* distal, ×7600.

CYLINDRALITHUS NUDUS Bukry, n. sp.

Description.—This doubly flaring cylindrical form has an elliptical central opening that lacks any cross structure. The central opening has eccentricity of 1.1 to 1.8 and occupies 27 to 44 percent of the greatest outer diameter. In ?proximal view, 2 or 3 cycles of elements are present. The outer wall cycle contains 22 to 25 radial aligned elements. The 1 or 2 narrow inner cycles contain 19 to 24 elements in the outermost and 11 to 17 elements in the inner.

Remarks.—The lack of any central plate or cross structures is characteristic. The 1 or 2 inner cycles of elements forming a smooth outline for the central area are unique among species of *Cylindralithus.*

Size.—Maximum diameter, 5.6 μ.

Types.—Holotype, UI-H-2976 (Pl. 20, fig. 7). Paratypes, UI-H-2972 through UI-H-2975.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-4, S-11.* Known range, Santonian-Campanian.

Illustrations.—Plate 20, figures 7-8; 7, holotype, UI-H-2976, *LW-4*, ×10,800; 8, UI-H-2975, *LW-4*, ×10,100.

CYLINDRALITHUS SCULPTUS Bukry, n. sp.

Description.—This cylindrical form, with only 9 or 10 external, vertical fluted ridges, tapers little, if at all. Above the narrow base are 3 scalloped depressions in the interridge areas.

Remarks.—This form was observed only in side view. No other species of *Cylindralithus* has this kind of cylinder structure.

Size.—Maximum diameter, 5.2 μ.

Types.—Holotype, UI-H-2977 (Pl. 20, fig. 9).

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4.* Known range, Campanian.

Illustrations.—Plate 20, figures 9-10; 9, holotype, UI-H-2977, *LW-4*, side, ×6460; 10, UI-H-3622, *LW-4*, side, ×5810.

CYLINDRALITHUS SERRATUS Bramlette & Martini

Cylindralithus serratus Bramlette & Martini, 1964, p. 310, pl. 5, fig. 18-20.——Gartner, 1968, p. 47, pl. 10, fig. 9.

Cylindralithus crassus Stover, 1966, p. 141, pl. 4, fig. 31-33; pl. 5, fig. 1; pl. 9, figs. 8-9.

Remarks.—Instead of a strong taper or median flexure, this form tapers slightly out from a serrate base. Better preservation and slightly larger size appear to have resulted in the distinction of *Cylindralithus crassus.*

Size.—Maximum diameter, 5.9 μ.

Types.—Hypotypes, UI-H-2963 through UI-H-2966.

Occurrence.—*LW-4.* Known range, Santonian-Maastrichtian.

Illustrations.—Plate 20, figures 11-12; 11, UI-H-2964, *LW-4*, side, ×8550; 12, UI-H-2966, *LW-4*, side, ×7130.

Organ genus LITHASTRINUS Stradner, 1962

LITHASTRINUS FLORALIS Stradner

Lithastrinus floralis Stradner, 1962, p. 370, pl. 2, fig. 6-11.——Stradner, 1963, pl. 2, fig. 8-8a.——Manivit, 1965, p. 194, pl. 2, fig. 5a-c.——Gartner, 1968, p. 47, pl. 21, fig. 13a-d; pl. 22, fig. 28-29; pl. 24, fig. 12a-d.

Eprolithus floralis (Stradner), Stover, 1966, p. 149, pl. 7, fig. 4-7, 9; pl. 9, fig. 21.

Lithastrinus mortatus Stover, 1966, p. 149, pl. 7, fig. 20.

Remarks.—Stradner in his original description designated a preparation as the holotype. He illustrated the new form with six figures and did not indicate a holotype. This syntype suite shows enough variation to include *Eprolithus* Stover and *Lithastrinus mortatus* Stover. The range of variation within the Austin Chalk and Taylor Marl samples further supports a close connection of these forms. The central area width is variable; when not closed by the rays it shows a plate composed of several elements, with 6 to 9 ray forms dominant. The illustration given by Stradner, 1962 (pl. 2, fig. 8) is designated as the lectotype of *Lithastrinus floralis.* Stradner's illustrations (pl. 2, fig. 6-7, 9-11) are designated paralectotypes.

Size.—Maximum diameter, 6.9 μ.

Types.—Hypotypes, UI-H-2909, UI-H-2910.

Occurrence.—Localities and samples, *B-8?, PB-50, PH-8, PS-1, PSA, PT-6, Q-7, S-1, S-3, S-4.* Known range, Albian-Campanian.

Illustrations.—Plate 21, fig. 1-2; 1, UI-H-2909, *S-1*, ×8080; 2, UI-H-2910, *Q-7*, ×7600.

LITHASTRINUS GRILLI Stradner

Lithastrinus grilli Stradner, 1962, p. 369, pl. 2, fig. 1-5.——Stradner, 1963, pl. 2, fig. 9-9a.——Gartner, 1968, p. 47, pl. 18, fig. 1-2; pl. 20, fig. 17; pl. 21, fig. 1, 11; pl. 22, fig. 26.

Remarks.—Electron micrographs of this form agree well with the original figures of Stradner. Some modifications are noted. The basic structure is a short cylinder with 6 or 7 conical rays arising at each end. A typical star-shaped outline results. The small recessed central areas of the star-shaped ends are composed of several small elements which are distinctive because of their smooth surfaces which contrast with the irregular surface of the rest of the nannofossil. One end always has shorter rays. A few specimens with extremely long rays were observed from the lower Taylor Marl. As lectotype of the species a form illustrated by Stradner (1962, pl. 2, fig. 2) is here designated, and as paralectotypes others figured in the same work (pl. 2, fig. 1, 3-5).

Size.—Maximum diameter, 10.7 μ.

Types.—Hypotypes, UI-H-2911 through UI-H-2913, UI-H-2994, UI-H-3623.

Occurrence.—Localities and samples, *LW-3, LW-4, N-0, N-100, PS-1, Q-7, S-4, S-10.* Known range, Turonian-Campanian.

Illustrations.—Plate 21, figures 3-6; 3, UI-H-2912, *LW-4*, ×8750; 4, UI-H-2913, *LW-4*, ×6650; 5, UI-H-2911, *LW-4*, ×7600; 6, UI-H-3623, *S-10*, ×8080.

Organ genus STEPHANOLITHION Deflandre, 1939

STEPHANOLITHION LAFFITTEI Noël

Stephanolithion laffittei Noël, 1956, p. 318, pl. 2, fig. 5-6.——Noël, 1958, p. 161, pl. 1, fig. 1-2.——Stradner, 1963, p. 178, pl. 1, fig. 4a-c.

Stephanolithion sp. cf. *S. laffittei* Bramlette & Martini, 1964, p. 320, pl. 6, fig. 12-15.

Stephanolithion laffittei Noël, 1965, p. 83, text-fig. 15-16; pl. 6, fig. 3-5.

Stephanolithion Black, 1965, p. 133, fig. 11.

Stephanolithion laffittei Manivit, 1965, p. 191, pl. 2, fig. 21.

Stephanolithion crenulatum Stover, 1966, p. 160, pl. 7, fig. 25-27; pl. 9, fig. 25-27.

Stephanolithion laffittei Maresch, 1966, p. 383, pl. 3, fig. 5.——Reinhardt, 1966, p. 41, pl. 23, fig. 23; pl. 21, fig. 19.

Corollithion octoradiatum Gartner, 1968, p. 35, pl. 6, fig. 5a-c; pl. 10, fig. 14-15; pl. 11, fig. 7a-c; pl. 22, fig. 19.

Remarks.—This species is a short tapering cylinder. The smaller circular base has 8 radial arms extending from the rim to the center. The typical *Stephanolithion* processes that extend from the periphery of the large opening may or may not be present. Peripheral processes were observed on only 26 of the 60 specimens examined. Counts of 1 to 7 processes were made. The cylinder wall, or rim cycle, is composed of 17 to 27 rod-shaped radial elements that produce a corrugated external surface. At the small end of the cylinder, the wall elements interfinger with a second cycle of 21 to 26 elements that form a rim for the 8 radial bars. As a result, proximal views show a rim count that is twice that observed for the rim in distal view. Technically, the wall cycle slopes adcentrally, and the basal cycle slopes abcentrally. With 8-arm forms dominating, only a few 9-arm forms were observed. Stover noted a range of 6-12 (usually 9 or 10) arms for his Aptian-Cenomanian forms.

Size.—Maximum diameter, 5 μ.

Types.—Hypotypes, UI-H-3579 through UI-H-3588.

Occurrence.—*ALB, B-8, LW-1, LW-2, LW-4, N-0, N-100, PB-50, PH-8, PSA, PS-1, PT-6, Q-6, SF-11, S-1, S-3, S4.* Known range: Callovian-Maastrichtian.

Illustrations.—Plate 21, figures 7-11; 7, UI-H-3588, *S-3,* distal, ×10,100; 8, UI-H-3585, *S-3,* proximal, ×9440; 9, UI-H-3586, *LW-4,* proximal, ×9500; 10, UI-H-3582, *B-8,* proximal, ×9500; 11, UI-H-3581, *LW-2,* proximal, ×9030.

Family SYRACOSPHAERACEAE Lemmermann, 1908

Subfamily SYRACOSPHAEROIDEAE Kamptner, 1928

Genus COSTACENTRUM Bukry, n. gen.

Description.—The elliptical forms have 2 distinct rims each composed of a single cycle of elements. No significant imbrication is observed and distal rim elements are radial. The distinctive central-area crossbar structures are recessed below the distal rim surface. The central area is lined by an adcentrally sloping cycle of elements. No stem structure occurs.

Type species.—*Coccolithus horticus* STRADNER, ADAMIKER, & MARESCH.

Remarks.—Although these forms originally were referred to *Coccolithus* SCHWARZ, the relatively narrow rims and distinctive crossbar structures, recessed in the central area, are distinguishing features.

COSTACENTRUM HORTICUM (Stradner, Adamiker, & Maresch), Bukry, n. comb.

Tremalithus sp. PIENAAR, 1966, p. 154, pl. 1, fig. 4-6.

Coccolithus horticus STRADNER, ADAMIKER, & MARESCH, 1966, p. 337, pl. 2, fig. 4, text-fig. 1-2.

Coccolithus horticus GARTNER, 1968, p. 18, pl. 10, fig. 2; pl. 25, fig. 6-8; pl. 26, fig. 1.

Remarks.—Rim counts of 32 to 44 elements were made. The mean value is 36.

Size.—Maximum diameter, 6.6 μ.

Types.—Hypotypes, UI-H-3055 through UI-H-3059.

Occurrence.—Localities and samples, *LW-4, PS-1, PSA, Q-6, S-1, S-2, S-3, S-4, S-6, WR, 42a.* Known range, Albian-Campanian.

Illustrations.—Plate 21, figure 12; Plate 22, figures 1-4.——Pl. 21, fig. 12, UI-H-3059, *LW-4,* distal, ×5490.——Pl. 22, fig. 1-4; 1, UI-H-3058, *S-1,* distal, ×9030; 2, UI-H-3055, *LW-4,* distal, ×14,600; 3, UI-H-3056, *S-3,* proximal, ×8080; 4, UI-H-3057, *LW-4,* proximal, ×12,800.

COSTACENTRUM LOWEI Bukry, n. sp.

Description.—This elliptical coccolith is composed of a proximal and distal rim and a large, open central area spanned by a distinctive cross structure. The central area has an eccentricity of 1.5, 1.8, 1.9, and 1.9 in the specimens studied. The center structure is a cross coinciding with the long and short axes of the ellipse. In addition another crossbar forms a complete elliptical ring just inside the central-area margin. These bars are all in the same plane and composed of numerous small elements. The rims are composed of 32 to 36 elements. In proximal view, the proximal rim elements incline slightly clockwise. The distal rim inclines slightly counterclockwise or is radial. Imbrication in both rims is probably slight.

Remarks.—*Costacentrum lowei* is strikingly similar to *C. horticum,* but is readily distinguished by its oval-and-cross structure in the central area.

Size.—Maximum diameter, 5.8 μ.

Types.—Holotype, UI-H-3063, distal view (Pl. 22, fig. 6). Primary paratype, UI-H-3060, proximal view (Pl. 22, fig. 5). Other paratypes, UI-H-3060 through UI-H-3062.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis Co., Texas. Localities and samples, *LW-4, N-0, N-100.* Known range, Coniacian-Campanian.

Illustrations.—Plate 22, figures 5-6; UI-H-3060, *N-100,* proximal, ×10,100; 6, holotype, UI-H-3063, *LW-4,* distal, ×10,800.

Organ genus CRIBROSPHAERA Arkhangelsky 1912

CRIBROSPHAERA EHRENBERGI Arkhangelsky

Cribrosphaera ehrenbergi ARKHANGELSKY, 1912, p. 412, pl. 6, fig. 19-20.

Cribrosphaera murrayi ARKHANGELSKY, 1912, p. 411, pl. 6, fig. 17-18.

Cribrosphaerella ehrenbergi (Arkhangelsky) DEFLANDRE in Piveteau, J. (ed.), 1952, p. 111, text-fig. 54a-b.——VEKSHINA, 1959, p. 70, pl. 2, fig. 9.

Cribrosphaerella murrayi VEKSHINA, 1959, p. 71, pl. 2, fig. 10.

Cribrosphaerella romanica REINHARDT, 1964, p. 756, pl. 2, fig. 1, text-fig. 7.

Cribrosphaerella murrayi BLACK, 1965, p. 133, fig. 13.

Cribrosphaera ehrenbergi Arkhangelsky, REINHARDT, 1966, p. 28, pl. 22, fig. 13, 26, text-fig. 8.

Cribrosphaera matthewsi (Black), REINHARDT, 1966, p. 28, pl. 5, fig. 1-2; pl. 12, fig. 5, text-fig. 7.

Cretadiscus colatus GARTNER, 1968, p. 36, pl. 10, fig. 7-8; pl. 12, fig. 5a-c, 6a-b; pl. 19, fig. 10a-d.

Cretadiscus polyporus GARTNER, 1968, p. 36, pl. 1, fig. 17-19; pl. 4, fig. 13; (not) pl. 25, fig. 5.

Cribrosphaerella ehrenbergi GARTNER, 1968, p. 40, pl. 1, fig. 14-15; pl. 3, fig. 2a-d; pl. 6, fig. 7a-c; pl. 14, fig. 2a-d; pl. 15, fig. 11a-d.
Cribrosphaerella linea GARTNER, 1968, p. 40, pl. 1, fig. 16; pl. 3, fig. 4a-d; pl. 11, fig. 16a-c.
Cribrosphaerella sp. GARTNER, 1968, p. 41, pl. 4, fig. 17; pl. 14, fig. 10; pl. 20, fig. 7.

Remarks.—Cretadiscus GARTNER was separated from *Cribrosphaera* ARKHANGELSKY on the basis of rim-element configuration. While *Cribrosphaera* has at least 2 rim cycles, *Cretadiscus* was assumed to have a single rim cycle with 2 keel projections mimicking 2 rim cycles. This distinction is questioned on the basis that these two genera can only be distinguished in side views. Even then, one could not be sure that secondary coalescing of 2 rims had not occurred. Since the genera cannot be distinguished in either proximal or distal views, *Cretadiscus* is not separated from *Cribrosphaera*. Most species attributed to *Cribrosphaera* are readily attributable to the type species.

In distal view, the rim cycle is composed of 15 to 30 radially oriented or slightly counterclockwise-inclined elements. Patterned structure of small elements in the central area forms 8 to 79 perforations, arranged in concentric cycles. The eccentricity of the coccolith outline varies from 1.0 to 1.4. In proximal view 2 distinct rim tiers are seen. The rim elements are radial or inclined clockwise. Central-area structure duplicates that seen in distal view. Members of a continuous series showing increasing central-area proportion and perforation counts are observed throughout the Santonian and Campanian samples examined. In particular, well-preserved specimens of the complete series were observed in the lower Taylor Marl sample *LW-4*.

Size.—Maximum diameter, 10.6 μ.

Types.—Hypotypes, UI-H-3191, UI-H-3192, UI-H-3194, UI-H-3196 through UI-H-3208.

Occurrence.—Localities and samples, *B-8, B-22, KG-11, LW-1, LW-2, LW-3, LW-4, N-0, N-100, PB-50, PH-8, PS-1, PSA, S-1, S-3, S-4, S-6, S-10, S-11, SF-10, SF-11*. Known range, Aptian-Maastrichtian.

Illustrations.—Plate 22, figures 7-12; 7, UI-H-3197, *S-3*, proximal, ×10,800; 8, UI-H-3208, *LW-4*, distal, ×8080; 9, UI-H-3196, *B-8*, distal, ×4520; 10, UI-H-3198, *LW-4*, proximal, ×11,500; 11, UI-H-3206, *LW-4*, proximal, ×7600; 12, UI-H-3191, *LW-4*, distal, ×10,100.

CRIBROSPHAERA LAUGHTONI (Black), Bukry, n. comb.

Favocentrum laughtoni BLACK, 1964, p. 313, pl. 53, fig. 1-2.
Favocentrum matthewsi BLACK, 1964, p. 314, pl. 53, fig. 5-6.
Cretadiscus polyporus GARTNER, 1968 *(partim)*, p. 36, pl. 25, fig. 5.

Remarks.—Favocentrum BLACK was separated from *Coccolithus* SCHWARZ because of a unique granular central area. Examination of 70 specimens of this genus shows that the rim structure and central-area structure is very similar to *Cribrosphaera ehrenbergi* in all respects except for lack of perforations. Minor variation in element counts was used to distinguish species. The variation noted is here considered to be intraspecific, and the type species, *F. laughtoni* BLACK, is designated as a species of *Cribrosphaera*. This species is distinguished by the absence of a regular set of throughgoing perforations. In distal view, the rim is composed of 16 to 25 elements that are radial or inclined slightly counterclockwise. In proximal view, 2 rim cycles identical with those of *C. ehrenbergi* are observed. In both views the central area is a closed mosaic of small elements. A continuous series ranges from forms with wide rims and few central elements to narrow rims and numerous central-area elements. This series parallels that observed in *C. ehrenbergi*.

Size.—Maximum diameter, 9.8 μ.

Types.—Hypotypes, UI-H-3209 through UI-H-3219, UI-H-3193, UI-H-3195.

Occurrence.—Localities and samples, *B-8, B-22, LW-1, LW-2, N-100, PH-8, PSA, S-1, S-2, S-3, S-4, S-6, S-10, S-11, SF-10, SF-11, WR, 42a, 42g*. Known range, Santonian-Maastrichtian.

Illustrations.—Plate 23, figures 1-9; 1, UI-H-3212, *WR*, distal, ×7000; 2, UI-H-3213, *KG-11*, distal, ×8550; 3, UI-H-3219, *B-8*, proximal, ×6650; 4, UI-H-3215, *B-8*, proximal, ×6460; 5, UI-H-3217, *B-8*, distal, ×7130; 6, UI-H-3193, *S-6*, proximal, ×8090; 7, UI-H-3216, *B-8*, distal, ×5170; 8, UI-H-3210, *B-22*, distal detail, ×16,300; 9, UI-H-3195, *SF-11*, proximal, ×6180.

CRIBROSPHAERA PELTA (Gartner), Bukry, n. comb.

Cribrosphaerella pelta GARTNER, 1968, p. 41, pl. 10, fig. 24-25.

Remarks.—This species has 3 distinct rim tiers in proximal view. The small central area is oval to oblong in outline and pierced by 3 to 16 perforations. This form has been observed only from the Taylor Marl.

Size.—Maximum diameter, 7 μ.

Types.—Hypotypes, UI-H-3220 through UI-H-3223.

Occurrence.—Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 23, figures 10-12; 10, UI-H-3220, *LW-4*, proximal, ×7550; 11, UI-H-3222, *LW-4*, distal, ×9440; 12, UI-H-3223, *LW-4*, proximal, ×9030.

Genus DISCOLITHINA Loeblich & Tappan, 1963

[*nom. subst. pro Discolithus* HUXLEY, 1868]

Remarks.—The type species, *Discolithina vigintiforata* KAMPTNER, was originally described as having a single rim and shield. According to W. W. HAY (personal communication), however, electronmicrography of topotype material shows that the type species is probably a multirimmed syracosphaerid. Until further electronmicroscope work is done, assignment of forms to *Discolithina* is considered questionable.

DISCOLITHINA? FURLONGII Bukry, n. sp.

Description.—This strongly elliptical form has an eccentricity of 1.6. The rather broad rim cycle is composed of 34 dextrally imbricated elements which have a very slight clockwise inclination. The central area is filled by a cycle of 17 flat elements which also are dextrally imbricated and have radial sutures. One side of the central-area cycle overlaps onto the other but not completely so that minor openings occur. The external margin of the discolith is smooth. Since the rim is higher than the central area, the specimen illustrated is probably shown in proximal view.

Remarks.—The high rim count and equant elements distinguish this form from *Discolithina? hallii* and *D.? pagei*. The dextral imbrication of the central area cycle is also a distinguishing feature.

Size.—Maximum diameter, 3.3 μ; maximum width, 2.0 μ.

Types.—Holotype, UI-H-3153, ?proximal view (Pl. 24, fig. 1).

Occurrence.—Type stratigraphic source, Aachen marl. Type locality, Aachen, Germany. Locality and sample, *B-22*. Known range, Campanian.

Illustration.—Plate 24, figure 1, holotype, UI-H-3153, *B-22*, ?proximal, ×18,200.

DISCOLITHINA? HALLII Bukry, n. sp.

Description.—This is an elliptical discolith with eccentricity of 1.3 to 1.6. It is monolamellar with low relief. A narrow rim cycle contains 14 to 18 elements which have radial sutures. Immediately within the cycle is another narrower cycle of 14 elongate elements elevated so as to separate the rim cycle from the central area. The latter is composed of 2 or 3 cycles of flat plates, at least 2 of which are prominent. The outer cycle imbricates sinistrally, while the innermost cycle imbricates dextrally. No clear boundary is seen between the 2 cycles. It is estimated that 20 to 30 plates make up the entire central area.

Remarks.—*Discolithina? hallii* is similar in some respects to *D.? pagei*, but is distinguished by its additional rim cycle and by the 2 oppositely imbricating cycles in the central area.

Size.—Maximum diameter, 5.7 μ.

Types.—Holotype, UI-H-3155, distal view (Pl. 24, fig. 2). Paratypes, UI-H-3154, 3156.

Occurrence.—Type stratigraphic source, Aachen marl. Type locality, Aachen, Germany. Locality and sample, *B-22*. Known range, Campanian.

Illustrations.—Plate 24, figures 2-4; 2, holotype, UI-H-3155, *B-22*, distal, ×12,500; 3, UI-H-3156, *B-22*, distal, ×10,400; 4, UI-H-3154, *B-22*, distal, ×9560.

DISCOLITHINA? PAGEI Bukry, n. sp.

Description.—This is a small, simply constructed, monolamellar elliptical discolith with eccentricity of 1.4 to 1.5. The narrow, scalloped rim cycle is made of 14 elements inclined slightly clockwise in distal view. A cycle of 10 or 11 large flat plates composes the entire central area. In distal view, these plates imbricate sinistrally and incline clockwise. In proximal view, the sutures incline slightly counterclockwise.

Remarks.—Simplicity of structure is distinctive.

Size.—Maximum diameter, 3.7 μ.

Types.—Holotype, UI-H-3158, distal view (Pl. 24, fig. 5). Primary paratype, UI-H-3157, proximal view (Pl. 24, fig. 6).

Occurrence.—Type stratigraphic source, Aachen marl. Type locality, Aachen, Germany. Locality and sample, *B-22*. Known range, Campanian.

Illustrations.—Plate 24, figures 5-6; 5, holotype, UI-H-3158, *B-22*, distal, ×15,400; 6, UI-H-3157, *B-22*, proximal, ×18,900.

DISCOLITHINA? POLYGONATA (Gorka), Bukry, n. comb.

Discolithus polygonatus GORKA, 1963, Acta Palaeontologica Polonica, v. 8, no. 1, p. 14, text-pl. 1, fig. 8-9, pl. 1, fig. 5-6.

Remarks.—The corrugated appearance of the rim cycle and irregular pattern of the central-area elements are distinctive. *Discolithina polygonata* was figured, anonymously, from a chalk crayon by ECHOLS & LEVIN in 1963 (Micropaleontology, v. 10, no. 1, p. 80). The specimen figured here has 37 radial elements in the rim cycle.

Size.—Maximum diameter, 3.4 μ.

Types.—Hypotype, UI-H-3159.

Occurrence.—Locality and sample, *B-22*. Known range, Campanian-Maastrichtian.

Illustration.—Plate 24, figure 7, UI-H-3159, *B-22*, distal, ×14,500.

DISCOLITHINA? POROSUTURALIS Bukry, n. sp.

Description.—The outline of this elliptical form has an eccentricity of 1.4 to 1.5. A single very narrow rim cycle contains 23 to 26 radially oriented elements. The central area is apparently constructed of 4 elements with 2 digitate margins that roughly occupy a quadrant each. Two of the diametrically opposite quadrant elements are smaller than the others. The digitate margins form 3 lines of perforations. Approximately aligned with the long axis of the ellipse, the long line of perforations is double. The 2 short perforation lines are offset from each other but are aligned with the short axis of the ellipse. Short perforation lines, with 3 perforations, curve to incline counterclockwise at the periphery of the coccolith in distal view. The long perforation lines, with 10 perforations, curve to incline clockwise at the periphery. In proximal views, the curvatures are reversed.

Remarks.—The entire coccolith is only slightly convex in distal view. The apparent 4-element structure distinguishes this form from other species of *Discolithina?*

Size.—Maximum diameter, 6 μ.

Types.—Holotype, UI-H-3162, distal view (Pl. 24, fig. 8). Primary paratype, UI-H-3163, proximal view (Pl. 24, fig. 9). Other paratypes, UI-H-3159, UI-H-3160, UI-H-3163.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 24, figures 8-10; 8, holotype, UI-H-3162, *LW-4*, distal, ×9500; 9, UI-H-3163, *LW-4*, proximal, ×12,000; 10, UI-H-3161, *LW-4*, proximal, ×14,600.

Organ genus NEPHROLITHUS Gorka, 1957

NEPHROLITHUS GORKAE Åberg

Nephrolithus gorkae Åberg, 1966, p. 64, pl. 1; pl. 2, fig. 1-6; pl. 3, fig. 1-6; text-fig. 1.

Size.—Maximum diameter, 6.3 μ.

Types.—Hypotypes, UI-H-3169, UI-H-3170.

Occurrence.—Locality and sample, *KG-11*. Known range, Maastrichtian.

Illustrations.—Plate 24, figures 11-12; 11, UI-H-3169, *KG-11*, distal, ×7130; 12, UI-H-3170, *KG-11*, distal, ×7130.

Subfamily ZYGODISCOIDEAE Bukry, n. subfam.

This large group of elliptical forms shares the common feature of one prominent rim cycle on each coccolith. This cycle imbricates dextrally and the elements usually incline clockwise in distal view. In vertical section, the distal surface slopes slightly abcentrally and the proximal surface of the rim slopes adcentrally. Usually a small secondary cycle of elements is present at the inner margin of the proximal side of the rim. A large variety of cross structures fills the central area. These structures commonly support a stem.

Organ genus AMPHIZYGUS Bukry, n. gen.

Description.—The smooth rim of these elliptical coccoliths is composed of only 1 cycle of radial elements. In the central area a central stem is supported by a complex crossbar along the short axis of the coccolith. The 2 perforations flanking the crossbar are each ringed by a small cycle of elements. In proximal view, a secondary cycle occurs at the central-area margin.

Type species.—*Amphizygus brooksii brooksii* Bukry, n. sp.

Remarks.—This genus is related to *Zygodiscus* Bramlette & Sullivan and *Chiastozygus* Gartner by rim structure. It is distinguished by the distinctive yoke of elements surrounding the perforations and by the nature of the crossbar structure which is intermediate to these genera.

AMPHIZYGUS BROOKSII BROOKSII Bukry, n. sp., n. ssp.

Description.—The smooth distal rim of this elliptical coccolith is composed of a single cycle of radial elements. A central stem and 2 circular perforations with distinctive yoke-cycles surrounding them dominate the central area. Eccentricities of the elliptical outline are 1.3 to 1.5. In distal view the rim cycle is made of 28 to 41 (31 mean) radial elements. The central area occupies 69 to 76 percent of the coccolith length; 2 large circular perforations are seen at each end of the elliptical central area. The width of the perforations is equivalent to 22 to 44 percent (30 percent mean) of the total coccolith width. A narrow circular cycle of 12 to 18 radially oriented elements surrounds the perforations. A central stem structure and the centers of the perforations all lie along the long axis of the coccolith. Bundles of rods supporting the multi-element stem are tangent to the perforation outlines and occur only near the short axis of the coccolith. In proximal view a radially oriented 32- to 36-element secondary cycle is present. The complete circular nature of the perforation yoke-cycles is best observed in this view.

Remarks.—This form is distinguished from *Zygodiscus* Bramlette & Sullivan and *Chiastozygus* Gartner by its distinctive yoke of elements around the perforations and by the intermediate nature of the stem-support structure. In *Zygodiscus* the support has the form of a short axis crossbar and in *Chiastozygus* it is an X-shaped crossbar. This type species is distinguished from the related *Amphizygus brooksii nanus* Bukry, n. sp., n. ssp., by larger perforation openings (narrower yoke cycle) and by lower rim counts.

Size.—Maximum diameter, 8 μ.

Types.—Holotype, UI-H-3394, proximal view (Pl. 25, fig. 2). Primary paratype, UI-H-3392, distal view (Pl. 25, fig. 1). Other paratypes, UI-H-3388 through UI-H-3393.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, South Dallas County, Texas. Localities and samples, *B-8, LW-1, LW-2, LW-4, PB-50, S-3, S-10, SF-11, 42a, WR*. Known range, Santonian-Campanian.

Illustrations.—Plate 25, figures 1-3; 1, UI-H-3392, *LW-1*, distal, ×7130; 2, holotype, UI-H-3394, *S-3*, proximal, ×7130; 3, UI-H-3390, *SF-11*, proximal, ×7130.

AMPHIZYGUS BROOKSII NANUS Bukry, n. sp., n. ssp.

Description.—The outline of this elliptical coccolith has eccentricity 1.2 to 1.4. In distal view the rim is composed of a single cycle of 30 to 40 (36 mean) elements that are radial and make a smooth rim outline. The central area occupies 67 to 70 percent of the coccolith length. Two small perforations with a broad yoke-cycle of 9 to 15 (12 mean) radial elements occur at each end of the central area. The width of these perforations is equivalent to only 9 to 19 percent (15 percent mean) of the total coccolith width. The bundles of rods supporting the central-stem structure are tangent to the perforation outlines near the short axis of the coccolith. In proximal view, a secondary rim cycle contains 30 to 41 (37 mean) radial to slightly clockwise inclined elements. The yoke cycle around the perforations is best seen in this view.

Remarks.—*Amphizygus brooksii nanus* Bukry, n. sp., n. ssp., is distinguished from *Amphizygus brooksii brooksii* Bukry, n. sp., n. ssp., by smaller perforations (broader yoke cycle) and by higher rim counts.

Size.—Maximum diameter, 8.9 μ.

Types.—Holotype, UI-H-3399, proximal view (Pl. 25, fig. 5). Primary paratype, UI-H-3397, distal view (Pl. 25, fig. 4). Other paratypes, UI-H-3395 through UI-H-3398.

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Localities and samples, *B-8, LW-4, S-11*. Known range, Santonian-Campanian.

Illustrations.—Plate 25, figures 4-7; 4, UI-H-3397, *B-8*, distal, ×5810; 5, holotype, UI-H-3399, *B-8*, proximal, ×6180; 6, UI-H-3396, *B-8*, proximal, ×6440; 7, UI-H-3398, *B-8*, distal, ×6460.

AMPHIZYGUS MINIMUS Bukry, n. sp.

Description.—The eccentricity of the elliptical outline is 1.2 to 1.4. In distal view the rim cycle is composed of 17 to 24 (21 mean) radial elements. In proximal view a secondary rim cycle has 20 to 24 elements which are more columnar than platelike. At their contact with the distal rim these elements are sinistrally imbricated, but lose imbrication before terminating proximally. The outer surface of this columnar cycle slopes adcentrally. A narrow cycle of 12 to 19 elements occurs just within the secondary cycle. The central area is composed entirely of the 2 7-element cycles outlining the perforations. These perforations occupy 8 to 17 percent (12 percent mean) of the total coccolith width. No evidence of any stem structure is observed.

Remarks.—The central area composed of only the perforation border elements distinguishes this species from other species of *Amphizygus*. The columnar nature of the secondary cycle and the occurrence of a regular lining cycle also serves to distinguish this species.

Size.—Maximum diameter, 4.6 μ.

Types.—Holotype, UI-H-3402, proximal view (Pl. 25, fig. 8). Primary paratype, UI-H-3403, distal view (Pl. 25, fig. 9). Other paratypes, UI-H-3400, UI-H-3401.

Occurrence.—Type stratigraphic source, type mid-Santonian marl. Type locality, Saintes, France. Localities and samples, *LW-1*, *SF-10*, *SF-11*. Known range, Santonian.

Illustrations.—Plate 25, figures 8-10; 8, holotype, UI-H-3402, *SF-11*, proximal, ×11,500; 9, UI-H-3403, *SF-10*, distal, ×9500; 10, UI-H-3400, *SF-11*, proximal, ×10,800.

AMPHIZYGUS PAPILLATUS Bukry, n. sp.

Description.—The eccentricity of the outline is 1.2 to 1.3. In proximal view the rim is composed of 20 to 31 radial elements. A secondary cycle of 22 to 32 slightly columnar radially oriented elements is present. The abcentrally sloping flanks and remainder of the central area have a pebbled or papillate-appearing mosaic of many small elements. Two small perforations have a width equal to only 9 to 13 percent of the total coccolith width.

Remarks.—No evidence of a stem structure in proximal view is seen. This form, like the similar *Amphizygus minimus* Bukry, n. sp., usually has a smaller proximal central area than specimens of the *Amphizygus brooksii* Bukry, n. sp., group. Central-area structure distinguishes this form from *A. minimus*. Instead of a large yoke cycle being dominant, it is small and inconspicuous in the mosaic of many similar-sized elements that compose the central area.

Size.—Maximum diameter, 6.3 μ.

Types.—Holotype, UI-H-3407, proximal view (Pl. 25, fig. 11). Paratypes, UI-H-3405, UI-H-3406.

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Localities and samples, *B-8*, *LW-2*, *LW-3*. Known range, Santonian-Campanian.

Illustrations.—Plate 25, figures 11-12; 11, holotype, UI-H-3407, *B-8*, proximal, ×8080; 12, UI-H-3405, *LW-3*, proximal, ×9500.

Organ genus ANGULOFENESTRELLITHUS Bukry, n. gen.

Description.—The smooth, narrow rim cycle is composed of 2 cycles of elements. The large central area is a network of polygonally framed perforations and is slightly convex distally. A small, slender stem occurs at the center.

Type species.—*Angulofenestrellithus snyderi* Bukry, n. sp.

Remarks.—This genus is distinguished from *Ethmorhabdus* by having 2 cycles of obviously imbricated elements instead of a single radial cycle. It is also distinguished by its larger number elements forming the polygonal perforation frames.

ANGULOFENESTRELLITHUS SNYDERI Bukry, n. sp.

Description.—This species is characterized by a narrow rim, a broad central area with large, polygonally framed perforations arranged in 1 to 3 cycles, and by a small hollow stem at the center. Eccentricities of the elliptical outline are 1.3 to 1.5. In distal view the rim is composed of an outer and narrow inner cycle of elements. The outer cycle has 34 to 58 (48 mean) elements that imbricate dextrally and incline clockwise. The inner cycle has 45 to 66 (58 mean) blocky elements which imbricate sinistrally and slope adcentrally. The distinctive central area occupies 72 to 82 percent of the coccolith length. Basically, the central area is composed of usually 2 cycles of polygonally outlined perforations. Each is formed by a cycle of 5 to 10 small elements. The network of these cycles comprises the central area. Perforations are arranged in the following patterns: an outer cycle with 7 to 16 (13 mean) perforations; an inner cycle with 2 to 14 (9 mean) perforations; a third cycle, where present, with 4 to 7 perforations; and a total average of 22 perforations in each specimen. In proximal view 3 rim cycles are visible and the central area duplicates that seen in distal view. Both of the inner cycles have 23 to 41 (31 mean) elements that imbricate slightly sinistrally and incline counterclockwise.

Remarks.—The most comparable form is *Ethmorhabdus gallicus* Noël, 1965. However, that species has a broad radially arranged rim with fewer (30) elements. The perforations are regularly hexagonal in outline. The new species is identified only from European samples.

Size.—Maximum diameter, 11 μ.

Types.—Holotype, UI-H-3368, distal view (Pl. 26, fig. 1). Primary paratype, UI-H-3367, proximal view (Pl. 26, fig. 2). Other paratypes, UI-H-3366, UI-H-3367, UI-H-3369 through UI-H-3372.

Occurrence.—Type stratigraphic source, Aachen marl. Type locality, Aachen, Germany. Localities and samples, *B-8, B-22.* Known range, Campanian.

Illustrations.—Plate 26, figures 1-3; 1, holotype, UI-H-3368, *B-22,* distal, ×6250; 2, UI-H-3367, *B-22,* proximal, ×9560; 3, UI-H-3372, *B-22,* distal, ×7300.

Organ genus CHIASTOZYGUS Gartner, 1968

CHIASTOZYGUS AMPHIPONS (Bramlette & Martini), Gartner

Zygodiscus? amphipons BRAMLETTE & MARTINI, 1964, p. 302, pl. 4, fig. 9-10.

Chiastozygus amphipons (Bramlette & Martini), GARTNER, 1968, p. 26, pl. 8, fig. 11-14, pl. 11, fig. 9a-c, pl. 22, fig. 10-11.

Remarks.—This form, with its approximately 20 to 40 dextrally imbricating and clockwise inclined (in distal view) elements is present in practically every sample studied. In proximal view the rim sutures are strongly inclined counterclockwise and there is a secondary inner cycle with radial sutures. The narrow X-shaped crossbars are formed by 2 lines of small elements. The outer margin is smooth or slightly serrate. A large central area opening is typical. This is a rather generalized species lacking the distinguishing characters of other associated *Chiastozygus* species.

Size.—Maximum diameter, 5.3 μ.

Types.—Hypotypes, UI-H-3415 through UI-H-3418.

Occurrence.—Localities and samples, *B-8, B-22, LW-1, LW-3, LW-4, N-0, N-100, PB-50, PH-8, PT-6, PSA, S-1, S-3, S-4, WR, 42a.* Known range, Santonian-Maastrichtian.

Illustrations.—Plate 26, figures 8-9; 8, UI-H-3416, *N-100,* distal, ×12,100; 9, UI-H-3418, *S-3,* proximal, ×10,100.

CHIASTOZYGUS BIFARIUS Bukry, n. sp.

Description.—Eccentricity of the serrate and smooth elliptical outlines is 1.2 to 1.3. There are 26 to 35 dextrally imbricating clockwise inclined rim elements. The inner margin of the broad rim forms a smooth oval outline to the small central area, which is filled by 4 broad crossbars meeting at the center to support a small cylindrical stem. The crossbars have a median suture and are built of laths aligned to this suture. The crossbars are symmetrical about the long and short axis of the ellipse.

Remarks.—A combination of features which distinguish this form include its small size, broad generally serrate rim, broad 2-part crossbars, smooth well-defined oval center, and slender central stem. The proportion of the long diameter occupied by the central area is 54 to 68 percent. This species was encountered only in Austin and Niobrara samples.

Size.—Maximum diameter, 5.5 μ.

Types.—Holotype, UI-H-3419, distal view (Pl. 26, fig. 10). Paratypes, UI-H-3420 through UI-H-3423.

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Shook Avenue, Dallas, Texas. Localities and samples, *LW-1, N-100, PS-1, PSA, Q-6, S-1, S-2, S-3, S-4, S-11, WR, 42a.* Known range, Santonian.

Illustrations.—Plate 26, figures 10-12; 10, holotype, UI-H-3419, *WR,* distal, ×9500; 11, UI-H-3423, *S-3,* distal, ×10,100; 12, UI-H-3420, *PS-1,* distal, ×8850.

CHIASTOZYGUS DISGREGATUS (Stover), Bukry, n. comb.

Discolithus disgregatus STOVER, 1966, p. 142, pl. 2, figs. 11-12; pl. 8, fig. 12.

Remarks.—The elliptical smooth outline of this form has eccentricity of 1.3 to 1.5. In distal view 26 to 34 (29 mean) elements imbricated dextrally and inclined clockwise form a narrow rim cycle. An inner cycle has 6 or 7 adcentrally sloping large elements which line the central area. The central area occupies 68 to 81 percent of the coccolith length and contains 4 broad bars which form an offset X-shaped crossbar. Two of the bars are aligned across the center, whereas the other two are distinctly offset. The bars have median sutures with at least 2 flanking elements. The median sutures make angles of 45° to 75° (56° mean) with the long axis of the coccolith. Distinct openings or depressions occur between the crossbars. This form has no central stem. Small size, low rim count, distinct inner cycle, and definite gaps between crossbars distinguish this form from the related *Chiastozygus planus* BUKRY, n. sp. The specimens figured here are 3.4 to 4.2 μ long, which is smaller than the 8 to 10 μ noted in the original description.

Size.—Maximum diameter, 4.2 μ.

Types.—Hypotypes, UI-H-3424 through UI-H-3429.

Occurrence.—Localities and samples, *B-8, B-22, 42a.* Known range, Santonian-Campanian.

Illustrations.—Plate 27, figures 1-4; 1, UI-H-3426, *42a,* distal, ×14,700; 2, UI-H-3429, *42a,* distal, ×14,000; 3, UI-H-3427, *42a,* distal, ×14,000; 4, UI-H-3428, *B-8,* distal, ×12,000.

CHIASTOZYGUS GARRISONII Bukry, n. sp.

Description.—The very narrow rim cycle of this form has eccentricity of 1.2 to 1.4. In distal view the rim cycle is composed of 31, 38, and 46 elements in the specimens observed. The short margins of these dextrally imbricated elements are perpendicular to the rim border, whereas the long inner margins are strongly inclined counterclockwise. A large open central area occupies 71 to 74 percent of the coccolith length. A thin X-shaped crossbar structure spans the opening to support a hollow stem. The crossbars, composed of at least 4 or 5 rows of small elements, flare at the rim. The 2 small and 2 large perforations formed have rounded outlines.

Remarks.—Large size and slender rim and crossbar structures distinguish this form from other species of *Chiastozygus.*

Size.—Maximum diameter, 8.4 μ.

Types.—Holotype, UI-H-3432, distal view (Pl. 27, fig. 6). Paratypes, UI-H-3430 and UI-H-3431.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4.* Known range, Campanian.

Illustrations.—Plate 27, figures 5-6; 5, UI-H-3430, *LW-4,* distal, ×8550; 6, holotype, UI-H-3432, *LW-4,* distal, ×6650.

CHIASTOZYGUS INTERRUPTUS Bukry, n. sp.

Description.—A large elliptical form, the eccentricity of the outline is 1.3 to 1.4. The rim is composed of 37, 38, 46, 48, and 58 elements in the specimens studied. In distal view the elements are dextrally imbricated and the sutures radial. The 4 broad crossbars do not meet at the center of the central area. Instead, a short fifth bar parallel to the long axis of the ellipse occupies the center. The 4 crossbars join, 2 on each end of the fifth bar. The 4 resulting perforations are equal in size and their outlines irregular. The central bar supports a tall stem. In proximal view the mid-line sutures of the bars are more apparent. Consequently, the central area appears to be composed of 4 perforated, polygonal fields.

Remarks.—This form has some gross similarities to the Tertiary *Zygolithus dubius* DEFLANDRE and the Upper Cretaceous *Chiastozygus synquadriperforatus* BUKRY, n. sp. It is distinguished by its tall, multi-element stem, 4 equant perforations, and fifth bar interrupting the crossbars.

Size.—Maximum diameter, 6.2 μ.

Types.—Holotype, UI-H-3435, proximal view (Pl. 27, fig. 7). Primary paratype, UI-H-3433, distal view (Pl. 27, fig. 8). Other paratypes, UI-H-3433, UI-H-3434, UI-H-3436.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm road 1382, South Dallas County, Texas. Localities and samples, *LW-4, PB-50, PT-6, S-11.* Known range, Santonian-Campanian.

Illustrations.—Plate 27, figures 7-8; 7, holotype, UI-H-3435, *S-11,* proximal ×8750; 8, UI-H-3433, *LW-4,* distal, ×8550.

CHIASTOZYGUS INTURRATUS (Reinhardt), Bukry, n. comb.

Eiffellithus turriseiffeli inturratus REINHARDT, 1965, p. 36, pl. 2, fig. 3; text-fig. 5.——REINHARDT, 1966, p. 38, pl. 8, fig. 2; pl. 11, fig. 3; text-fig. 19.

Remarks.—The elliptical rim is composed of 48 to 63 dextrally imbricate and radially sutured elements. On some specimens 5 to 7 of the rim elements are twice as wide as others. The very wide elements usually are spaced to create an apparent inner cycle which has an hexagonal inner margin. In both varieties the central area has a broad, X-shaped crossbar and a solid central stem. The crossbars are constructed of a central group of rods and broad row of wide elements flanking each side. In some specimens the crossbars are wide enough to close 2 or all of the open areas usually present. Eccentricities of 1.3 to 1.5 are observed for the elliptical outline. This form was probably attributed to *Eiffellithus turriseiffeli* by REINHARDT because the rim enlargements mimic the inner cycle of that species. The cross and stem structures are *Chiastozygus* type.

Size.—Maximum diameter, 7.8 μ.

Types.—Hypotypes, UI-H-3438 through UI-H-3441.

Occurrence.—Localities and samples, *B-8, B-22, KG-11, LW-1, LW-2, N-100, PB-50, PT-6, Q-7, S-1, S-3, S-4, S-9, S-10, S-11, SF-10, SF1], WR, 42a, 42g.* Known range, Albian-Maastrichtian.

Illustrations.—Plate 27, figures 9-11; 9, UI-H-3439, *S-9,* distal, ×9440; 10, UI-H-3438, *SF-10,* proximal, ×7600; 11, UI-H-3441, *S-1,* distal, ×5810.

CHIASTOZYGUS PLANUS Bukry, n. sp.

Description.—This elliptical coccolith with smooth or serrate margin has an eccentricity of 1.2 to 1.4. In distal view the rim cycle is composed of 25 to 49 (40 mean) elements that imbricate dextrally. The elements have prominent inner margins inclined clockwise. Immediately inside the rim cycle is a very narrow cycle of 5 to 8 elongate elements. The central area occupies 59 to 75 percent of the length of the coccolith. The prominent features of the central area are the median sutures of the 4 broad bars, which are composed of only a few large, planar elements (commonly 2) that completely fill the central area. Median sutures make an angle of 44° to 68° (58° mean) with the long axis of the ellipse. Though the 2 median sutures at one end of the ellipse intersect at a point on the long axis, the 2 points thus determined being separated by a distance approximately equal to the width of the narrowest part of the rim. Small depressions or gaps may occur between the crossbars. The form has no central stem.

Remarks.—This species is distinguished by offset crossbars that completely fill the central area and by the lack of a central stem. *Chiastozygus disgregatus* (STOVER) is similar but has a narrower rim cycle with fewer elements, a wider inner cycle, and openings between the crossbars.

Size.—Maximum diameter, 10.3 μ.

Types.—Holotype, UI-H-3442, distal view (Pl. 28, fig. 1). Paratypes, UI-H-3443 through UI-H-3446.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, South Dallas County, Texas. Localities and samples, *PT-6, S-3, S-11, WR, 42a.* Known range, Santonian.

Illustrations.—Plate 27, figure 12; Plate 28, figures 1-2.——Pl. 27, fig. 12, UI-H-3445, *S-3,* distal, ×6650.——Pl. 28, fig. 1-2; 1, holotype, UI-H-3442, *S-11,* distal, ×8750; 2, UI-H-3443, *PT-6,* distal, ×7130.

CHIASTOZYGUS PLICATUS Gartner

Chiastozygus plicatus GARTNER, 1968, p. 27, pl. 16, figs. 10-11; pl. 17, fig. 9a-d; pl. 19, fig. 9a-c; pl. 20, fig. 6; pl. 21, fig. 9a-c; pl. 22, fig. 12.

Remarks.—High number of rim elements, small size, circularity of the 2 perforations along the short axis of the ellipse, and in proximal view penetration of the crossbar terminations into the secondary cycle of elements help to define this species.

Size.—Maximum diameter, 8.4 μ.

Types.—Hypotypes, UI-H-3447 through UI-H-3450.

Occurrence.—Localities and samples, *LW-3, LW-4, N-100, S-3, S-10, S-11, 42a.* Known range, Santonian-Campanian.

Illustration.—Plate 28, figure 3, UI-H-3448, *LW-4,* proximal, ×9030.

CHIASTOZYGUS PROPAGULIS Bukry, n. sp.

Zygolithus concinnus Martini, PIENAAR, 1966, p. 154, pl. 1, figs. 1-3.

Neococcolithes aff. *N. dubius* (Deflandre) GARTNER, 1968, p. 29, pl. 5, fig. 12-13; pl. 7, fig. 9a-c.

Description.—This is a very small elliptical coccolith with an eccentricity of 1.4 to 1.5. In distal view the narrow rim is composed of dextrally imbricated and clockwise inclined elements. Rim counts of 22, 28, and 28 elements are observed. The 4 arms of the crossbar do not meet at the center of the coccolith. All 4 or 2 of the arms can be distinctly offset. In proximal view a secondary cycle of 28 radially aligned elements is present.

Remarks.—This form has been mistakenly attributed to the much larger *Zygrhablithus dubius* (DEFLANDRE) which has 5 bars forming the cross structure. *Zygolithus concinnus* MARTINI has a regular crossbar structure with no offset. No stem structure is observed. Small size and offset crossbar distinguish the new species described here.

Size.—Maximum diameter, 3.9 μ.

Types.—Holotype, UI-H-3453, distal view (Pl. 28, fig. 5). Primary paratype, UI-H-3451, proximal view (Pl. 28, fig. 4). Other paratypes, UI-H-3451 and UI-H-3452.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-4, PT-6, Q-6.* Known range, Santonian-Campanian.

Illustrations.—Plate 28, figures 4-5; 4, UI-H-3451, *Q-6,* proximal, ×19,200; 5, holotype, UI-H-3453, *LW-4,* distal, ×13,500.

CHIASTOZYGUS SYNQUADRIPERFORATUS Bukry, n. sp.

Description.—This is a structurally complex species. In distal view the rim is composed of 23 to 41 dextrally imbricated and clockwise inclined elements. The mean rim count is 29, and 70 percent of the 23 specimens counted have counts of 30 or less. The eccentricity of the elliptical outline is 1.3 to 1.5. The X-shaped crossbar in the central area is constructed of a narrow line of rods flanked by broad smooth laths on either side. The short arm of the cross makes a smaller angle with the short axis of the ellipse than the long arm. The most prominent structural feature of the central area, however, is the asymmetry of the crossbar flanks. The perforations formed all have a long axis that makes an angle of 18° to 35° with the long axis of the ellipse. The 2 perforations most closely aligned with the short axis of the ellipse are distinctly smaller than the others. In proximal view the asymmetrical alignment of the perforations is seen to be caused by the facade formed by the laths on the distal surface. Perforations between the crossbars are much larger and more equant on the proximal side of the coccolith. The proximal rim has a secondary cycle of elements that imbricate dextrally and are radial. The narrow crossbars are asymmetric to the ellipse axis. The crossbars have median sutures and rows of processes extending into the perforations. These processes are rarely preserved.

Remarks.—This species is distinguished from *Chiastozygus quadriperforatus* GARTNER by several features. Instead of 40 to 50 rim elements, counts of less than 30 are most common. In distal view the crossbars are not aligned with the short axis of the ellipse. Size and shape of perforations differ in different views. Processes extend into the perforations in proximal view.

Size.—Maximum diameter, 5.3 μ.

Types.—Holotype, UI-H-3458, distal view (Pl. 28, fig. 6). Primary paratype, UI-H-3459, proximal view (Pl. 28, fig. 8). Other paratypes, UI-H-3454 through UI-H-3457, UI-H-3459.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-3, LW-4, 42a.* Known range, Santonian-Campanian.

Illustrations.—Plate 28, figures 6-9; 6, holotype, UI-H-3458, *LW-4,* distal, ×10,100; 7, UI-H-3454, *LW-4,* proximal, ×12,800; 8, UI-H-3459, *LW-4,* proximal, ×10,100; 9, UI-H-3457, *LW-4,* distal, ×13,500.

Organ genus EIFFELLITHUS Reinhardt, 1965

EIFFELLITHUS AUGUSTUS Bukry, n. sp.

Eiffellithus turriseiffeli (Deflandre), GARTNER, 1968 *(partim),* pl. 2, fig. 22-23; pl. 3, fig. 13a-c; pl. 5, fig. 19; pl. 7, fig. 5a-c; pl. 9, fig. 5-9; p. 26, pl. 18, fig. 9-10; pl. 19, fig. 1a-d, 2a-d; pl. 23, fig. 8-11; pl. 24, fig. 2a-c.

Description.—This form has the typical inner and outer rim cycles of *Eiffellithus.* The broad crossbars bifurcate at the ends and are aligned with the long and short axis of the elliptical coccolith. The eccentricity of the outline is 1.2 to 1.4. In distal view the rim cycle is composed of 36 to 64 (53 mean) elements that imbricate dextrally and incline clockwise along their inner margin. The central area, which occupies 76 to 89 percent of the coccolith length, is composed of a broad cycle of 8 to 13 large elements and 2 broad crossbars aligned with the coccolith axes. The crossbars, composed of many small rods, support a large hollow central stem. Usually, gaps in the broad cycle accommodate the ends of crossbars. An elliptical opening may be present within the inner cycle bridged by crossbars. In proximal view the central opening is always observed within a broad secondary cycle which is inclined counterclockwise, just like the outer rim cycle. The crossbar, in proximal view, instead of being composed of a bundle of rods is made of 2 rows of block-shaped elements, the crossbars splitting as they approach the center and curving to join the adjacent crossbars. The splitting causes a diamond-shaped perforation at the center.

Remarks.—This form is distinguished from the related *Eiffellithus turriseiffeli* (Deflandre) REINHARDT by its broader crossbars aligned with the coccolith axes. The crossbars also differ in having bifurcating ends in distal view.

Size.—Maximum diameter, 13.3 μ.

Types.—Holotype, UI-H-3538, distal view (Pl. 28, fig. 10). Primary paratype, UI-H-3537, proximal view (Pl. 29, fig. 1). Other paratypes, UI-H-3533 through UI-H-3537, UI-H-3939 through UI-H-3543.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Polk Street at Ten Mile Creek, Dallas, Texas. Localities and samples, *B-8, LW-1, LW-2, LW-3, LW-4, N-100, PB-50, PH-8, PS-1, PSA, PT-6, Q-6, S-1, S-2, S-3, S-4, S-11, SF-10, SF-11, WR, 42a, 42g*. Known range, Santonian-Campanian.

Illustrations.—Plate 28, figures 10-12; Plate 29, figure 1.——Pl. 28, fig. 10-12; 10, holotype, UI-H-3538, *PSA*, distal, ×5700; 11, UI-H-3543, *LW-4*, distal, ×5490; 12, UI-H-3541, *LW-4*, distal, ×6460.——Pl. 29, fig. 1, UI-H-3537, *SF-11*, proximal, ×4850.

EIFFELLITHUS TURRISEIFFELI (Deflandre), Reinhardt

Zygolithus turriseiffeli DEFLANDRE in DEFLANDRE & FERT, 1954, p. 149, pl. 13, figs. 15-16; text-fig. 65.

Rhabdosphaera elliptica VEKSHINA, 1959, p. 74, pl. 1, fig. 10; pl. 2, figs. 14a-b.

Zygrhablithus turriseiffeli (Deflandre) DEFLANDRE, 1959, p. 135. ——MANIVIT, 1966, p. 191, pl. 2, fig. 1a-d.

Rhabdolithus turriseiffeli STRADNER, 1963, p. 180, pl. 5, figs. 9-9a.

Zygrhablithus? turriseiffeli BRAMLETTE & MARTINI, 1964, p. 304, pl. 3, figs. 18-21; pl. 4, figs. 1-2.

Eiffellithus turriseiffeli REINHARDT, 1965, p. 32.——REINHARDT, 1966, p. 38.——GARTNER, 1968 *(partim)*, p. 26, pl. 2, fig. 22-23; pl. 3, fig. 13a-c; pl. 5, fig. 19; pl. 7, fig. 5a-c; pl. 9, fig. 5-9; pl. 13, fig. 1a-c, 2a-c; pl. 16, fig. 1-2; pl. 17, fig. 3a-d; pl. 18, fig. 8; pl. 22, fig. 4; pl. 23, fig. 7; pl. 24, fig. 1a-c; pl. 25, fig. 15-16; pl. 26, fig. 3a-c, 4a-c; not pl. 18, fig. 9-10; pl. 19, fig. 1a-d, 2a-d; pl. 23, fig. 8-11; pl. 24, fig. 2a-c.

Clinorhabdus turriseiffeli STOVER, 1966, p. 138, pl. 3, figs. 1-9.

Remarks.—This common Upper Cretaceous form has elliptical outlines with eccentricity ranging from 1.1 to 1.7. In distal view the rim cycle is composed of 33 to 66 (46 mean) elements that imbricate dextrally and incline clockwise along their long inner margin. The central area is very large, occupying 80 to 86 percent of the coccolith length. A broad inner cycle of 7 to 15 (10 mean) polygonal elements in the central area encloses a small central opening, which is spanned by an X-shaped crossbar. The elongate opening is usually apparent only along the long axis of the ellipse. The crossbars usually meet at 90°; if they vary, the small angles are aligned with the short axis of the ellipse. A tall hollow stem rises from the crossbar. In proximal view the rim surface slopes adcentrally and the elements incline counterclockwise. The bars supporting the stem meet to form a square base. Two styles of construction are noted. A minor variety has enlarged crossbars which are multiserial (constructed of 4 or more rows of small elements) instead of biserial. The variety also has the higher rim counts and more circular outlines (Pl. 29, fig. 2-3).

Size.—Maximum diameter, 9.3 μ.

Types.—Hypotypes, UI-H-3544 through UI-H-3560.

Occurrence.—Localities and samples, *B-8, B-22, F-14, KG-11, LW-1, LW-2, LW-4, N-100, PB-50, PS-1, PSA, PT-6, PT-13, Q-4, Q-6, S-1, S-2, S-3, S-4, S-11, SF-11, WR, 42a, 42g*. Known range, Albian-Maastrichtian.

Illustrations.—Plate 29, figures 2-5; 2, UI-H-3559, *LW-4*, distal, ×7130; 3, UI-H-3548, *B-8*, proximal, ×5170; 4, UI-H-3558, *S-3*, distal, ×6650; 5, UI-H-3560, *LW-4*, distal, ×8080.

Organ genus HETEROMARGINATUS Bukry, n. gen.

Description.—This elliptical form has a 2-cycle rim of moderate width. In distal view the outer element cycles are radial and the inner-cycle elements, which are recessed below the outer, are strongly inclined. In the central area are 2 biserial axial crossbars. A central stem occurs. Four auxiliary bars connect the crossbars. In proximal view, a secondary cycle of radial elements is present in the rim.

Type species.—*Heteromarginatus wallacei* BUKRY, n. sp.

Remarks.—This form resembles *Vagalapilla* BUKRY, n. gen., in having an elliptical outline and major axial crossbars. It is distinguished by recessed inner rim cycle and distinctive, diamond-shaped frame in the central area.

HETEROMARGINATUS WALLACEI Bukry, n. sp.

Description.—The eccentricity of the elliptical outline is 1.4 to 1.5. There are 27 and 29 radial elements in the outer rim cycle of the specimens counted. In distal view the inner rim cycle is recessed below the outer cycle and is composed of 25 or 28 dextrally imbricated and strongly clockwise inclined elements. In proximal view the inner cycle sutures are radially aligned. A narrow secondary cycle of about 35 radial elements is at the juncture of the inner and outer cycles. The central area occupies 70 to 76 percent of the coccolith length and the unique crossbar structures are included there. Crossbars constructed of 2 rows of elements are aligned with the long and short axes of the coccolith. Arising from and extending between the junctures of the crossbars to the rim are 4 monoserial bars constructed of about 7 elements each. This set of bars forms a diamond-shaped frame which with the axial crossbars produces 4 perforations around the central stem. Four large oblong openings occur between the diamond-shaped frame and the inner rim margin.

Remarks.—In light microscope this form might be mistaken for *Vagalapilla elliptica* (GARTNER) or *Costacentrum lowei* BUKRY, n. sp. The general patterns are similar, even though the structural detail is distinct. *Watznaueria porta* BUKRY, n. sp., has a similar distal rim but lacks any crossbars and has a proximal shield.

Size.—Maximum diameter, 4.8 μ.

Types.—Holotype, UI-H-3387, distal view (Pl. 29, fig. 6). Primary paratype, UI-H-3386, proximal view (Pl. 29, fig. 7). Other paratypes, UI-H-3385, UI-H-3386.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 29, figures 6-7; 6, holotype, UI-H-3387, *LW-4*, distal, ×12,100; 7, UI-H-3386, *LW-4*, proximal, ×7600.

Organ genus PARHABDOLITHUS Deflandre, 1952

PARHABDOLITHUS ANGUSTUS (Stradner), Bukry, n. comb.

Rhabdolithus angustus STRADNER, 1963, p. 178, pl. 5, figs. 6-6a.
Parhabdolithus elongatus STOVER, 1966, p. 144, pl. 6, figs. 16-19; pl. 9, fig. 18.
Ahmuellerella angusta REINHARDT, 1966, p. 25, pl. 22, figs. 9-12.

Remarks.—This form has a strikingly oblong outline with eccentricities of 1.6 to 2.7. The 2 long parallel sides distinguish this form from other *Parhabdolithus* species. The central area is greatly restricted and filled by a few polygonal elements and a hollow stem with dextrally inclined elements in the wall. In distal view 40 to 58 rim elements are radially aligned or slightly inclined clockwise. The distal surface of the rim slopes strongly adcentrally along the inner portion. A narrow outer portion ("brim") slopes slightly abcentrally (Pl. 29, fig. 8, 11).

Size.—Maximum diameter, 6.1 μ.

Types.—Hypotypes, UI-H-3507 through UI-H-3516.

Occurrence.—Localities and samples, *B-22, F-14, LW-2, LW-4, N-0, N-100, PB-50, PH-8, PS-1, PSA, PT-6, Q-6, S-1, S-3, S-4, S-6, S11, WR, 42a*. Known range, Neocomian-Campanian.

Illustrations.—Plate 29, figures 8-11; 8, UI-H-3515, *LW-4*, side, ×7130; 9, UI-H-3513, *LW-4*, distal, ×12,800; 10, UI-H-3510, *PB-50*, distal, ×7130; 11, UI-H-3514, *LW-4*, distal, ×8750.

PARHABDOLITHUS FISCHERI Bukry, n. sp.

Description.—This elliptical to oblong species has a very broad rim cycle and a mosaic-like central area. In the oblong forms the rim may be as wide as the central area. In proximal view the rim elements are radial or inclined counterclockwise. Imbrication is dextral. Rim counts of 54 to 100 are noted, with counts of 54 to 74 the most frequent. A secondary cycle of small elements occurs at the inner margin of the rim. Usually more elements are seen in this cycle than in the rim cycle. In both distal and proximal views the central area is a featureless field of 50 to 500 tiny elements. At the center of the field is a small stem in distal view and a small depression in proximal view.

Remarks.—This form is distinguished from the related *Parhabdolithus angustus* (STRADNER) and *P. granulatus* STOVER by its broader rim with more elements and by its very large number of tiny elements which fill the central field.

Size.—Maximum diameter, 10.5 μ.

Types.—Holotype, UI-H-3523, proximal view (Pl. 30, fig. 2). Primary paratype, UI-H-3525, distal view (Pl. 29, fig. 12). Other paratypes, UI-H-3517 through UI-H-3522, UI-H-3524, UI-H-3525.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Polk Street at Ten Mile Creek, Dallas, Texas. Localities and samples, *B-8, B-22, LW-2, LW-4, PB-50, PH-8, PS-1, PSA, PT-6, S-11, WR, 42a, 42g*. Known range, Santonian-Campanian.

Illustrations.—Plate 29, figure 12; Plate 30, figures 1-3.——Pl. 29, fig. 12; UI-H-3525, *LW-4*, distal, ×10,800.——Pl. 30, fig. 1-3; 1, UI-H-3519, *LW-4*, proximal, ×5040; 2, holotype, UI-H-3523, *PSA*, proximal, ×5810; 3, UI-H-3520, *42a*, proximal, ×6250.

PARHABDOLITHUS GRANULATUS Stover

Parhabdolithus granulatus STOVER, 1966, p. 144, pl. 6, figs. 11-15; pl. 9, fig. 17.

Remarks.—This form was found in samples from Albian to Campanian. The rim cycle is composed of 34 to 42 elements inclined slightly clockwise and imbricated dextrally in distal view. The central area is a mosaic of relatively large, polygonal-outline elements and a central stem. The central area occupies 55 to 78 percent of the coccolith length. This species is distinguished from *Parhabdolithus fischeri* BUKRY, n. sp., by its fewer and larger elements in the central area and by its lower rim counts. *P. angustus* (STRADNER) is distinguished by its 2 long parallel sides.

Size.—Maximum diameter, 7 μ.

Types.—Hypotypes, UI-H-3526 through UI-H-3532.

Occurrence.—Localities and samples, *ALB, B-8, F-14, LW-1, LW-2, LW-4, N-100, PB-50, PH-8, PS-1, PT-6, PSA, Q-4, S-1, S-4, S-9, S-10, S-11*. Known range, Neocomian-Campanian.

Illustrations.—Plate 30, figures 4-7; 4, UI-H-3529, *PH-8*, distal, ×12,100; 5, UI-H-3531, *LW-4*, distal, ×13,500; 6, UI-H-3526, *LW-4*, proximal, ×15,200; 7, UI-H-3527, *N-100*, proximal, ×11,500.

PARHABDOLITHUS REGULARIS (Gorka), Bukry, n. comb.

Tremalithus regularis GORKA, 1957, p. 246, pl. 2, fig. 4.
Rhabdolithus regularis (Gorka) STRADNER, 1963, p. 180, pl. 5, figs. 5-5a.
Actinozygus regularis (Gorka) GARTNER, 1968, p. 23, pl. 3, fig. 12a-d; pl. 5, figs. 17-18; pl. 6, figs. 17a-c, 18a-c; pl. 12, fig. 11a-c.

Remarks.—This form is distinguished from the similar appearing *Vagalapilla octoradiata* (GORKA) by having 8 regularly spaced bars instead of 4 axially oriented bifurcating bars. The distal rim in *Parhabdolithus regularis* also slopes adcentrally and has 38 to 44 rim elements which are dextrally imbricated and radial.

Size.—Maximum diameter, 6.5 μ.

Types.—Hypotypes, UI-H-2895 through UI-H-2898.

Occurrence.—Locality and sample, *LW-4*. Known range, Campanian-Maastrichtian.

Illustrations.—Plate 30, figures 8-10; 8, UI-H-2898, *LW-4*, distal, ×7600; 9, UI-H-2897, *LW-4*, distal, ×7600; 10, UI-H-2895, *LW-4*, distal, ×9050.

Organ genus PERCIVALIA Bukry, n. gen.

Description.—The unique feature of this elliptical genus is seen in proximal view. Within the radial, narrow outer rim cycle is a broad abcentrally sloping inner rim cycle. This inner rim area is composed of 6 to 16 very narrow tiers of elements. Elements in adjacent tiers are offset. The central area may be bridged by a single crossbar structure or be filled by a perforated plate of many elements.

Type species.—Percivalia porosa BUKRY, n. sp.

Remarks.—The rim structure of this genus is unique.

PERCIVALIA PONTILITHA Bukry, n. sp.

Description.—This elliptical coccolith has the same distinctive tiers of elements that occur in the proximal view of *Percivalia porosa* BUKRY, n. sp. Instead of a complex central-area structure only a single bar bridges the area. The eccentricity of the apparent margin is 1.3 to 1.5. In proximal view the inner part of the rim is composed of 14 to 16 tiers of 13 to 17 elements each. The rim surface is abcentrally sloped. Elements in adjacent tiers are regularly offset to create a distinctive "woven" aspect. In the outer part of the rim the edges of 3 overlapping cycles of about 36 radially aligned elements are observed. The actual peripheral rim cycle is largely removed from all the specimens examined. The elements that remain allow an estimate of 36 radial elements to be made. The central area is a narrow opening that occupies 47 to 52 percent of the coccolith length. However, a wide crossbar along the short axis of the ellipse fills in 44 to 63 percent of the central area and thus forms 2 perforations. The crossbar is constructed of 5 to 13 small rows of elements aligned with the ellipse short axis.

Remarks.—No distal views of this form were observed. This species shares the same style rim with *Percivalia porosa* BUKRY, n. sp., but is easily distinguished by the single crossbar and smaller number of elements in the inner-tier cycles.

Size.—Maximum diameter, 6.8 μ.

Types.—Holotype, UI-H-3384, proximal view (Pl. 30, fig. 11). Paratypes, UI-H-3381 through UI-H-3383.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 30, figures 11-12; Plate 31, figure 1.——Pl. 30, fig. 11-12; 11, holotype, UI-H-3384, *LW-4*, proximal, ×8080; 12, UI-H-3382, *LW-4*, proximal, ×8750.——Pl. 31, fig. 1, UI-H-3383, *LW-4*, proximal, ×10,800.

PERCIVALIA POROSA Bukry, n. sp.

Description.—This elliptical coccolith has eccentricities of 1.2 to 1.4. The outer rim cycle of about 35 elements is preserved only on specimens seen in proximal view in this study. Distinctive feature of the genus is the inner portion of the proximal rim. There are 6 to 11 (8 mean) narrow tiers of 30 to 42 (34 mean) elements in the abcentrally sloping portion of the rim. Adjacent tiers always have their elements offset, creating an overall "woven" effect. The distal surface of the inner portion of the rim is structurally indeterminate. Some specimens show 2 partial cycles: an outer cycle of about 30 dextrally imbricated elements inclined clockwise and an equally indistinct inner cycle of about 30 radial elements. Rim distinction of the new genus is based on the unique structure revealed in proximal view.

The central area of this species is quite distinctive. In distal view, the outer cycle of 15 to 23 (18 mean) perforations is formed by a series of radially aligned hourglass-shaped elements. One end of these elements meets the rim freely, while the other (inner) end joins adjacent elements to form a low ridge demarcating the remainder of the central area. A second circuit of perforations within the ridge is smaller, and numbers 8 to 17 (13 mean) perforations. Two specimens have a third cycle of 9 perforations. The inner cycles are also constructed of hourglass-shaped and smaller connecting elements. Overall, 24 to 44 (32 mean) total perforations occur in the central area. No crossbars, as such, are seen but a long-axis suture and in some specimens a short-axis suture is present. At the center a short slender stem in 16 of the specimens studied has a small perforation on either side within the long-axis suture.

Remarks.—Perforations in one specimen have several processes, meeting at the centers to create a set of small perforations.

Size.—Maximum diameter, 7.4 μ.

Types.—Holotype, UI-H-3373, distal view (Pl. 31, fig. 2). Primary paratype, UI-H-3375, proximal view (pl. 31, fig. 3). Other paratypes, UI-H-3374 through UI-H-3380.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 31, figures 2-5; 2, holotype, UI-H-3373, *LW-4, distal*, ×7050; UI-H-3375, *LW-4*, proximal, ×8850; UI-H-3377, *LW-4*, distal, ×7600; UI-H-3379, *LW-4*, proximal, ×7600.

Organ genus PONTILITHUS Gartner, 1968

PONTILITHUS COMPLEXUS Bukry, n. sp.

Description.—This species has eccentricities of 1.3 to 1.5. In proximal view the rim cycle has 42 to 50 sinistrally imbricated elements inclined strongly counterclockwise. The secondary cycle has 43 to 52 dextrally imbricated and slightly counterclockwise inclined elements. Well-preserved specimens have a battlement structure at the boundary of the rim and secondary cycle. A complex crossbar aligned with the short axis of the ellipse dominates the central area. The large number of diagonal bars here do not maintain a 45° angle with the long axis of the ellipse. Instead, they fan out from the crossbar which is composed of numerous coalesced monoserial bars. Some specimens have a small circular opening in the center of the crossbar.

Remarks.—The broad coalescent short-axis crossbar and fanning diagonal bars distinguish this species from

Pontilithus obliquicancellatus GARTNER, type species of the genus. The structure of the proximal rim and in some specimens a perforation visible at the distal surface suggest that these forms may be allied with *Zygodiscus.* No specimens with serrate margins were observed.

Size.—Maximum diameter, 5.7 μ.

Types.—Holotype, UI-H-3414, proximal view (pl. 26, fig. 6). Paratypes, UI-H-3411 through UI-H-3413.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4.* Known range, Campanian.

Illustrations.—Plate 26, figures 6-7; 6, holotype, UI-H-3414, *LW-4,* proximal, ×7600; 7, UI-H-3412, *LW-4,* proximal, ×9440.

PONTILITHUS OBLIQUICANCELLATUS Gartner

Pontilithus obliquicancellatus GARTNER, 1968, p. 65, pl. 23, fig. 27.

Remarks.—This elliptic coccolith with an eccentricity of 1.3 to 1.4 has a serrate or smooth margin. In proximal view the rim cycle is built of 40 to 50 sinistrally imbricated elements strongly inclined counterclockwise. The proximal surface of the outer rim cycle slopes adcentrally. A broad secondary cycle of elements has essentially radial sutures. Well-preserved specimens show a battlement structure at the boundary of the rim and secondary cycle, which slopes slightly from this boundary toward the center of the coccolith. A unique set of narrow bars running from the central area margin to the transverse bars, in line with the long and short ellipse axes, occupies the central area. The narrow bars generally make a 45° angle with the long-axis bar. Since these secondary bars are essentially perpendicular to the rim margin, the result is 4 quadrant sets of bars, with diametrically opposite sets having the same orientation. Each quadrant has 3 to 5 diagonal bars. A small central opening is outlined at the center of the central area. Each discrete bar is monoserial and composed of very small block elements. This form was initially described from the Eagle Ford Shale of Texas.

Size.—Maximum diameter, 7.1 μ.

Types.—Hypotypes, UI-H-3408 through UI-H-3410.

Occurrence.—Localities and samples, *Q-5, S-1, S-2.* Known range, Turonian-Santonian.

Illustrations.—Plate 26, figures 4-5; 4, UI-H-3410, *S-1,* proximal, ×9440; 5, UI-H-3408, *Q-5,* proximal, ×7130.

Organ genus VAGALAPILLA Bukry, n. gen.

Description.—These elliptical coccoliths have a single rim composed of a single cycle of elements that imbricate dextrally in distal view. The long inner margin of these rim elements has a strong clockwise inclination in distal view. While the distal surface of the rim slopes slightly abcentrally, the proximal surface slopes strongly adcentrally. In proximal view a secondary cycle of elements occurs at the central area margin. The elliptical central area opening is partially filled by a set of crossbars aligned with long and short axes of the ellipse. The crossbars usually show bilateral symmetry with respect to a median suture. A hollow or solid stem structure may be present at the center of the cross. The stems extend only from the distal surface. No stem structures extend from the proximal surface. The rim margin is commonly smooth and the number of elements composing the rim ranges from 20 to 50 for species thus far assigned to this genus.

Type species.—*Vekshinella imbricata* GARTNER.

Remarks.—Several species previously referred to *Vekshinella* and *Staurolithites* should be included in this new genus. In 1959 VEKSHINA named a new monotypic genus *Ephippium,* from the Cretaceous. Her holotype specimen of the type species, *E. acutiferrus* VEKSHINA, was drawn in plan and side views. The species was described as having an elliptical, monolamellar rim, axial crossbars, and a short spine on one side and a long spine on the other at the cross center. Measurements of 4 specimens of this species were recorded. In 1963 LOEBLICH & TAPPAN transferred *E. acutiferrus* to *Vekshinella* because they found that the name *Ephippium* is preoccupied. In 1968 GARTNER emended *Vekshinella* to include monolamellar, elliptical forms with axial crossbars, whether they were surmounted by a spine or not. None of the 5 species assigned by GARTNER to the genus has spines on both sides, as would be required by the original monotypic definition of the genus. Another genus, *Staurolithites,* was described by CARATINI (1960) to include forms with a rim and any sort of crossbars, so long as they were in the plane of the rim. CARATINI made no mention of a spine but noted the similarity of the new genus to *Discolithus,* which lacks any spine structure. He further noted that his use of "-ites" was meant to indicate that he considered *Staurolithites* to be a collective genus.

Neither *Vekshinella* nor *Staurolithites* is satisfactory for designation of numerous species that meet the restricted definition of *Vagalapilla* described above. The key distinctions of the new genus are the consistent axial alignment of the crossbars and observation that any stem or spine extends only from the distal surface.

VAGALAPILLA AACHENA Bukry, n.sp.

Description.—The eccentricity of the outline is 1.3 to 1.6 (1.4 mean). In distal view the rim cycle is composed of 34 to 46 (41 mean) elements that imbricate dextrally. The most prominent margin of the rim elements is radially oriented, while the inner margin is inclined clockwise. The central area and its crossbars occupy 60 to 80 percent (71 percent mean) of the coccolith length. These axial crossbars are broad and composed of several lath-shaped elements arranged along a median suture. The ends of the crossbars flare and become quite wide where they meet the rim. Though no distinct stem is observed, the disjunction of elements at the center indicates that one could be present. In proximal view the rim cycle inclines counterclockwise and imbricates dextrally. A small secondary cycle of elements occurs at the inner margin of the rim. A narrow lining of irregular elements is seen just within the rim. Crossbars, in proximal view, are composed of several small blocky elements arranged in 2 rows.

Remarks.—Smooth outline, flaring of "plated" crossbar ends, high rim count and large central area are distinctive features of this species.

Size.—Maximum diameter, 7 μ.

Types.—Holotype, UI-H-3460, distal view (Pl. 31, fig. 7). Primary paratype, UI-H-3466, proximal view (Pl. 31, fig. 9). Other paratypes, UI-H-3461 through UI-H-3467.

Occurrence.—Type stratigraphic source, Aachen marl. Type locality, Aachen, Germany. Localities and samples, *B-8, B-22, LW-1, S-10, 42a*. Known range, Santonian-Campanian.

Illustrations.—Plate 31, figures 6-9; 6, UI-H-3461, *B-22*, distal, ×8850; 7, holotype, UI-H-3460, *B-22*, distal, ×7800; 8, UI-H-3467, *B-8*, proximal, ×8550; 9, UI-H-3466, *B-22*, proximal, ×8080.

VAGALAPILLA COMPACTA COMPACTA Bukry, n. sp. n. ssp.

Description.—The eccentricity of this strongly ellipitcal form is 1.4 to 1.5. In distal view the rim cycle is made of 24, 26, and 28 elements in the specimens studied. They are dextrally imbricated and have inner margins inclined clockwise. The rim outline is slightly serrate. Directly inside the rim cycle a narrow cycle of about 8 elongate elements lines the central area. This cycle has relatively large adcentrally sloping faces. The central area is filled by a set of subaxial crossbars. Median sutures divide each crossbar into 2 rows of a few large irregular elements. No central stem occurs. In proximal view the rim cycle elements are dextrally imbricated and inclined counterclockwise. A secondary cycle of 26 radial elements occurs at the margin of the central area. The crossbar structure resembles that seen in distal view.

Remarks.—A combination of characters serve to distinguish this species from others placed in *Vagalapilla*. The very broad, stemless crossbars composed of a few elements, serrate outline, and inner cycle lining the central area characterize this species. The serrate outline and lack of order distinguish it from *V. compacta integra* Bukry, n. sp., n. ssp.

Size.—Maximum diameter, 5.5 μ.

Types.—Holotype, UI-H-3470, distal view (Pl. 31, fig. 11). Primary paratype, UI-H-3469, proximal view (Pl. 31, fig. 10). Other paratypes, UI-H-3468, UI-H-3469.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, South Dallas County, Texas. Localities and samples, *PSA, S-3*. Known range, lower Santonian.

Illustrations.—Plate 31, figures 10-11; 10, UI-H-3469, *PSA*, proximal, ×12,900; 11, holotype, UI-H-3470, *S-3*, distal, ×9440.

VAGALAPILLA COMPACTA INTEGRA Bukry, n. sp., n. ssp.

Description.—This elliptical subspecies has eccentricity of 1.3 to 1.4. The rim cycle has a smooth outline and is composed of 23 to 27 dextrally imbricated elements. In distal view the most prominent margin of these elements is radial or inclined slightly counterclockwise. The longer inner margin is inclined clockwise. A broad subaxial cross fills the central area which occupies 63 to 71 percent of the coccolith length. This cross has recessed median sutures formed by broad flanking elements. One or 2 elements occur on either side in each bar.

Remarks.—The inner cycle lining the central area in *Vagalapilla compacta compacta* Bukry, n. sp., n. ssp., is reduced to an incomplete cycle of a few narrow elements. The subspecies is distinguished by smooth outline, reduced inner cycle, fewer crossbar elements, and by generally better ordered construction.

Size.—Maximum diameter, 5.7 μ.

Types.—Holotype, UI-H-3471, distal view (Pl. 31, fig. 12). Paratypes, UI-H-3472, UI-H-3473.

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Locality and sample, *B-8*. Known range, Campanian.

Illustration.—Plate 31, figure 12, holotype, UI-H-3471, *B-8*, distal, ×9500.

VAGALAPILLA DENTATA DENTATA Bukry, n. sp., n. ssp.

Description.—In distal view the smooth elliptical outline of this form has eccentricity of 1.2 to 1.5 (1.5 mean). The rim cycle contains 24 to 32 (29 mean) dextrally imbricated elements with a radial short margin and strongly clockwise inclined long inner margin. The central area occupies 59 to 69 percent of the coccolith length. Four broad, axial bars with median sutures divide the central area into quadrants. The straight-line sutures are formed by 1 or 2 long flat elements on either side. Each of the 4 kidney-shaped quadrant openings is invaded by 4 or 5 processes which arise from the crossbars. The processes are at the proximal level of the openings. In proximal view the outer rim cycle slopes adcentrally and the elements are dextrally imbricated and inclined counterclockwise. A secondary cycle of 28 radially oriented elements borders the central area. No stem structure is present.

Remarks.—The central-area structure is similar to that of *Broinsonia dentata* Bukry, n. sp., but the rim structure is entirely different. Although the rim structure is typical of *Vagalapilla* species, the central area dentation is unique in this genus. Rim ribs (crystallite lamellae?) are commonly noted on specimens from sample *LW-4*.

Size.—Maximum diameter, 8.5 μ.

Types.—Holotype, UI-H-3172, distal view (Pl. 32, fig. 3). Primary paratype, UI-H-3173, proximal view (Pl. 32, fig. 2). Paratypes, UI-H-3171, UI-H-3173 through UI-H-3177.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 32, figures 1-3; 1, UI-H-3177, *LW-4*, distal, ×10,100; 2, UI-H-3173, *LW-4*, proximal, ×12,800; 3, holotype, UI-H-3172, *LW-4*, distal, ×13,800.

VAGALAPILLA DENTATA APERTA Bukry, n. sp., n. ssp.

Description.—The eccentricity of this elliptical form is 1.4. In proximal view the narrow rim cycle is composed of 32 or 36 elements that imbricate dextrally and incline counterclockwise in the specimens observed. A small secondary cycle has 32, 34, or 40 radially aligned elements. The large central area occupies 72 to 76 percent of the coccolith length. The narrow axial crossbars are symmetric about a median suture that is outlined by small checker-arranged elements. Six or 7 long processes extend from these crossbars into the 4 open quadrants of the central area. In each quadrant 2 processes extend from the short axis and 4 or 5 extend from the long axis.

Remarks.—This form is very similar to *Vagalapilla dentata dentata* BUKRY, n. sp., n. ssp. It is distinguished by narrower rims, narrower crossbars, greater number of processes, greater number of elements, and by generally more open appearance.

Size.—Maximum diameter, 7.3 μ.

Types.—Holotype, UI-H-3178, proximal view (Pl. 32, fig. 5). Paratypes, UI-H-3179, UI-H-3180.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustrations.—Plate 32, figures 4-6; 4, UI-H-3179, *LW-4*, proximal, ×12,100; 5, holotype, UI-H-3178, *LW-4*, proximal, ×12,800; 6, UI-H-3180, *LW-4*, proximal, ×11,500.

VAGALAPILLA DORFII Bukry, n. sp.

Description.—This species has eccentricity of 1.2. In distal view the smooth narrow rim is composed of a single cycle of 34 elements that imbricate dextrally and incline clockwise along their inner margin. The large open central area occupies 68 to 74 percent of the coccolith length in the specimens observed. The 2 perpendicular crossbars are composed of a multitude of small elements and are aligned with the long and short axes of the ellipse. Margins of the crossbars are very linear. At the intersection of the crossbars is a circular hollow stem. In proximal view 34 dextrally imbricate and counterclockwise inclined elements compose the rim. In addition, a narrow secondary cycle of 34 essentially radial elements occupies the inner half of the rim. The crossbars have the same multi-element structure which they show in distal view.

Remarks.—The trace of the secondary proximal cycle can be seen in the electronmicrograph distal view (Pl. 32, fig. 8). This species is distinguished from other *Vagalapilla* species by regular and almost circular curvature of the narrow rim, large central area, slender linear crossbars composed of a multitude of tiny elements in both proximal and distal views, and by the circular hollow stem.

Size.—Maximum diameter, 5.7 μ.

Types.—Holotype, UI-H-3487, distal view (Pl. 32, fig. 8). Primary paratype, UI-H-3486, proximal view (Pl. 32, fig. 7). Other paratypes, UI-H-3486.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-3*, *LW-4*. Known range, Campanian.

Illustrations.—Plate 32, figures 7-8; 7, UI-H-3486, *LW-3*, proximal, ×12,500; 8, holotype, UI-H-3487, *LW-4*, distal, ×9500.

VAGALAPILLA ELLIPTICA (Gartner), Bukry, n. comb.

Vekshinella elliptica GARTNER, 1968, p. 30, pl. 17, fig. 5a-d; pl. 25, figs. 26-27; pl. 26, fig. 7a-d.

Remarks.—The eccentricity of the smooth or serrate margin is 1.2 to 1.6 (1.3 mean). In distal view the rim is composed of 25 to 36 (32 mean) elements that imbricate dextrally and incline clockwise along the inner margin. The central area occupies 59 to 74 percent (65 percent mean) of the length of the coccolith. Two broad crossbars with distinct median sutures are aligned with the ellipse axes or are rotated slightly sinistrally. The bars are composed of numerous lath-shaped elements. A fluted circular stem at the crossbar intersection may be solid or hollow. In forms from the Austin Chalk and Niobrara Formation the rim to crossbar interareas are usually open. Taylor Marl specimens tend to be closed by accessory elements. This species is especially common at the top of the Niobrara Formation. Lower Austin Chalk specimens have consistently more serrate outlines than upper Austin Chalk or Taylor Marl specimens.

Size.—Maximum diameter, 5 μ.

Types.—Hypotypes, UI-H-3474 through UI-H-3485.

Occurrence.—Localities and samples, *B-8?*, *B-22?*, *C-4*, *LW-2*, *LW-3*, *LW-4*, *N-0*, *N-100*, *PB-50*, *PH-8*, *PSA*, *PT-6*, *S-3*, *S-4*, *S-11*, *WR*. Known range, Turonian-Campanian.

Illustrations.—Plate 32, figures 9-12; 9, UI-H-3475, *N-100*, proximal, ×13,500; 10, UI-H-3480, *LW-4*, distal, ×12,100; 11, UI-H-3484, *LW-4*, distal, ×8550; 12, UI-H-3485, *LW-4*, proximal, ×10,100.

VAGALAPILLA IMBRICATA IMBRICATA (Gartner), Bukry, n. comb.

Vekshinella imbricata GARTNER, 1968, p. 30, pl. 9, figs. 16-17; pl. 13, figs. 8a-c, 9a-c.

Remarks.—This elliptical form has an outline eccentricity of 1.3. In distal view the 33 to 50 (38 mean) rim elements imbricate dextrally and incline clockwise. Each element has a radial and clockwise inclined margin visible, with one margin dominating. The open central area occupies 57 to 66 percent of the length of the coccolith. Two crossbars made of long rods are aligned with the ellipse axes. At the crossbar intersection a solid stem with square cross section is composed of long rods. Long stems spiral slightly. The outline of the rim is smooth.

Size.—Maximum diameter, 5.7 μ.

Types.—Hypotypes, UI-H-3488 through UI-H-3492.

Occurrence.—Localities and samples, *ALB*, *B-8*, *B-22?*, *LW-4*, *S-3*, *S-11*, *WR*. Known range, Albian-Campanian.

Illustrations.—Plate 33, figures 1-2; 1, UI-H-3490, *LW-4*, distal, ×9500; 2, UI-H-3489, *LW-4*, distal, ×10,800.

VAGALAPILLA IMBRICATA ELONGATA Bukry, n. ssp.

Description.—This subspecies of *Vagalapilla imbricata* (GARTNER) has a much more elongate outline, with eccentricity of 1.5 to 1.6. In distal view the rim is made of 29 to 33 elements. Rim elements are dextrally imbricated and inclined clockwise. The central area crossbars aligned with the ellipse axes are very broad. A solid stem with square cross section occurs at the intersection of the crossbars.

Remarks.—Distinct elongation, particularly broad long axis crossbar, and low rim count distinguish this subspecies from *Vagalapilla imbricata imbricata* (GARTNER).

Size.—Maximum diameter, 5.2 μ.

Types.—Holotype, UI-H-3497, distal view (Pl. 33, fig. 3). Paratypes, UI-H-3493 through UI-H-3496.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, South Dallas County, Texas. Localities and samples, *N-100, PSA, S-1, WR*. Known range, Santonian.

Illustrations.—Plate 33, figures 3-4; 3, holotype, UI-H-3497, *S-1*, distal, ×10,100; 4, UI-H-3495, *WR*, distal, ×10,100.

VAGALAPILLA OCTORADIATA (Gorka), Bukry, n. comb.

Discolithus octoradiatus GORKA, 1957, p. 259, pl. 4, fig. 10.

Zygolithus octoradiatus (Gorka) STRADNER, 1963, p. 180, pl. 5, fig. 2-2a.

Zygolithus? octoradiatus BRAMLETTE & MARTINI, 1964, p. 304, pl. 4, fig. 15-16.

Ahmuellerella limbitenuis REINHARDT, 1964, p. 751, text-fig. 1; pl. 1, fig. 6; pl. 2, fig. 6.——REINHARDT, 1966, p. 24, pl. 14, fig. 1, 3, 4; text-fig. 16.

Ahmuellerella octoradiata REINHARDT, 1966, p. 24, pl. 22, figs. 3-4.

Eiffellithus octoradiatus GARTNER, 1968, p. 25, pl. 2, fig. 17-21; pl. 3, fig. 11a-c; pl. 5, fig. 20; pl. 12, fig. 10a-c.

Remarks.—Many species of *Vagalapilla* show a circular stem supported by biserial crossbars approximately aligned with the long and short axes of the coccolith. In distal views the crossbars have lath-shaped elements on the surface, but proximal views show smaller blocky elements in the crossbars. Species of *Vagalapilla* also have simply constructed rims of a single cycle of dextrally imbricated elements of the same shape and alignment as occur in this species. High rim count and divergence of the crossbars along the median suture as they approach the rim distinguish this species, *V. octoradiata* (GORKA), from other species of the genus.

Size.—Maximum diameter, 7.6 μ.

Types.—Hypotypes, UI-H-3498 through UI-H-3506.

Occurrence.—Localities and samples, *B-8, B-22, F-14, LW-1, LW-2, LW-3, LW-4, N-100, PB-50, PH-8, PS-1, PSA, PT-6, Q-6, S-3, S-4, S-11, SF-11, WR, 42a, 42g*. Known range, Santonian-Maastrichtian.

Illustrations.—Plate 33, figures 5-7; 5, UI-H-3624, *LW-4*, distal, ×8080; 6, UI-H-3500, *LW-4*, distal, ×10,100; 7, UI-H-3625, *B-8*, proximal, ×8080.

Organ genus ZYGODISCUS Bramlette & Sullivan, 1961

ZYGODISCUS ACANTHUS Reinhardt

Zygodiscus acanthus REINHARDT, 1966, p. 40, pl. 15, fig. 5; pl. 23, fig. 8.

Remarks.—The distal rim is composed of 33 to 40 elements in an outer cycle with radial sutures and 32 to 34 elements in an inner cycle strongly inclined clockwise. Both cycles imbricate dextrally. A slender, solid stem arises from the narrow crossbar. Two large perforations account for the remainder of the central area. Eccentricities of the elliptical outline of the species vary from 1.2 to 1.4. This species is distinguished from the similar *Zygodiscus theta* (BLACK) by the presence of the distinctive serrate inner rim cycle in distal view.

Size.—Maximum diameter, 7.2 μ.

Types.—Hypotypes, UI-H-3322 through UI-H-3324.

Occurrence.—Localities and samples, *B-8, B-22, KG-11, S-4*. Known range, Albian-Maastrichtian.

Illustrations.—Plate 33, figures 8-9; 8, UI-H-3322, *B-22*, distal, ×11,000; 9, UI-H-3323, *KG-11*, distal, ×7600.

ZYGODISCUS BICLAVATUS Bukry, n. sp.

Zygodiscus biperforatus GARTNER, 1968, *(partim)*, p. 31, pl. 18, fig. 20.

Description.—The elliptical rim of the specimens studied contains 33 to 40 dextrally imbricated and clockwise inclined elements. Eccentricity of the outline is 1.2 to 1.6. A closed or open multi-element central stem occurs at the center of the central area. Two L-shaped elements are prominent in distal view. The short arm of each "L" borders the central stem, approximately parallel to the coccolith short axis. The long arm of the "L" arises from the rim surface at the extremities of the long axis of the coccolith.

Remarks.—This form is distinguished by its unusual pair of large L-shaped elements in distal view. None of the specimens studied showed complete perforations within the "L." Better-preserved specimens may show complete perforations. One illustration given by GARTNER (1968) shows a 48-element rim form with a single L-bar from the upper Austin Chalk at Dallas.

Size.—Maximum diameter, 6.7 μ.

Types.—Holotype, UI-H-3325, distal view (Pl. 10, fig. 11). Paratypes, UI-H-3326, UI-H-3327.

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Walnut Creek at Route 290, Austin, Texas. Locality and samples, *42a, 42g*. Known range, Santonian.

Illustrations.—Plate 33, figures 10-11; 10, UI-H-3326, *42a*, distal, ×8850; 11, holotype, UI-H-3325, *42a*, distal, ×8850.

ZYGODISCUS BIPERFORATUS Gartner

Zygodiscus biperforatus GARTNER, 1968, p. 73, pl. 14, figs. 15-16; pl. 17, figs. 1a-c, 2a-d; pl. 18, fig. 21; pl. 19, fig. 4a-d; pl. 20, figs. 19-20; pl. 21, fig. 5a-d.

Remarks.—Small, close-set perforations and high rim count give this species a unique appearance.

Size.—Maximum diameter, 10.5 μ.

Types.—Hypotypes, UI-H-3328 through UI-H-3330.

Occurrence.—Localities and samples, *LW-3, PB-50, WR.* Known range, Santonian-Campanian.

Illustrations.—Plate 33, figure 12, UI-H-3329, *LW-3,* distal, ×5170.

ZYGODISCUS COMPACTUS Bukry, n. sp.

Description.—This elliptical form has eccentricity of 1.2 to 1.5. The rim is broad and composed of 19 to 33 (28 mean) elements which imbricate dextrally with prominent sutures inclined slightly counterclockwise but turned to become strongly clockwise at the inner margin of the rim. The lateral bar crossing the central area is constructed of a poorly ordered group of elements. The crossbar may be a few large irregularly ordered intergrown rhombs or a more ordered group of smaller elements. The large blocky crossbar may fill the whole central area. No stem is associated with this form.

Remarks.—The broad rim and distinctly blocky crossbar serve to separate this from other *Zygodiscus* species. Though the margin is usually smooth, a few serrate specimens were observed, mostly from the lower Austin Chalk.

Size.—Maximum diameter, 7 μ.

Types.—Holotype, UI-H-3333, distal view (Pl. 34, fig. 2). Paratypes, UI-H-3331, UI-H-3332, UI-H-3334 through UI-H-3336.

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Localities and samples, *B-8, B-22, LW-1, LW-3, LW-4, N-0, N-100, PS-1, PSA, PT-6, Q-6, S-3, S-10, S-11, WR.* Known range, Coniacian-Campanian.

Illustrations.—Plate 34, figures 1-2; 1, UI-H-3331, *N-100,* distal, ×11,000; 2, holotype, UI-H-3333, *B-8,* distal, ×10,100.

ZYGODISCUS DEFLANDREI Bukry, n. sp.

Zygolithus diplogrammus Deflandre, BRAMLETTE & MARTINI, 1964, p. 304, pl. 4, figs. 11-12.

?*Zygolithus ponticulus* Deflandre, MANIVIT, 1966, p. 191.

Zygodiscus diplogrammus GARTNER, 1968, p. 32, pl. 14, fig. 18; pl. 17, fig. 4a-d; pl. 19, fig. 3a-d; pl. 21, fig. 2a-d; pl. 22, fig. 7; pl. 23, fig. 12-14; pl. 24, fig. 6a-d; pl. 25, fig. 17-18.

Description.—The rim of this elliptical form is composed of 30 to 46 dextrally imbricated and clockwise inclined elements. A stem of numerous small spiraled elements dominates the central area. Complete specimens have 2 small perforations flanking the stem at the rim margin and aligned with the short axis of the coccolith. This line of 3 perforations is bordered by 4 processes (2 on either side) which arise from the rim and meet along the long axis of the coccolith. The processes are wide at the rim margin and taper toward the center. Two large perforations occupy the remainder of the central area. In broken specimens, the central stem is removed but the 4 processes remain. The resulting forms show a long lateral slit between 2 apparent crossbars. Broken specimens of *Zygodiscus fibuliformis* REINHARDT may produce similar forms. Both of these broken forms have been referred to *Zygolithus diplogrammus* DEFLANDRE.

Remarks.—*Zygolithus diplogrammus* is a Miocene-Pliocene form with only 2 straight, continuous bars bridging the central area. References of Cretaceous forms with distinct stem structure and 3 perforations along the short axis to this taxon is questionable. Since broken specimens from at least 2 Cretaceous species could be attributed to it, such reference serves no useful purpose. A new restricted species is proposed for Cretaceous forms, *Zygodiscus deflandrei. Zygolithus ponticulus* DEFLANDRE, as originally described, has only a single thick bar crossing the central area.

Size.—Maximum diameter, 6.7 μ.

Types.—Holotype, UI-H-3338, distal view (Pl. 34, fig. 3). Paratypes, UI-H-3339, UI-H-3626.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *B-8, LW-4, N-11+8, N-100, PB-50?.* Known range, Albian-Maastrichtian.

Illustrations.—Plate 34, figures 3-5; 3, holotype, UI-H-3338, *LW-4,* distal, ×8080; 4, UI-H-3626, *LW-4,* proximal, ×8080; 5, UI-H-3339, *LW-4,* distal, ×8550.

ZYGODISCUS ELEGANS Gartner, emend. Bukry

Zygodiscus elegans GARTNER, 1968, p. 32, pl. 10, fig. 3-6, pl. 12, fig. 3a-c, 4a-c; pl. 27, fig. 1.

Remarks.—Rim element notching mentioned in the original description is a character that occurs in many taxa from the Taylor Marl. The same taxa from the Austin Chalk or Europe do not show this surface alteration. Distinction of *Zygodiscus elegans* from *Z. sisyphus* GARTNER is aided by the hollow stem of the latter unlike the solid stem of the former. The general size and proportions of their crossbars, stems, and rims overlap. The holotype of *Z. sisyphus* has a smooth rim margin with 33 elements, whereas that of *Z. elegans* has a smooth rim margin and 37 elements. Valid rim counts are difficult to make in light microscope. On the basis of electron-micrographs, I propose to include all smooth-outlined forms with 30 to 45 rim elements in *Z. elegans* emended. On the basis of paratype figures, *Z. sisyphus* is retained with modification.

Size.—Maximum diameter, 10.1 μ.

Types.—Hypotypes, UI-H-3598 through UI-H-3503.

Occurrence.—Localities and samples, *ALB, B-8, B-22, C-4, LW-1, LW-4, N-100, PB-50, Q-2, Q-6, S-4, S-11, 42a.* Known range, Albian-Campanian.

Illustrations.—Plate 34, figures 6-8; 6, UI-H-3598, *PB-50,* distal, ×9030; 7, UI-H-3601, *S-11,* distal, ×5490; 8, UI-H-3602, *LW-4,* proximal, ×10,800.

ZYGODISCUS FIBULIFORMIS (Reinhardt), Bukry, n. comb.

Glaukolithus fibuliformis REINHARDT, 1966, p. 41, pl. 9, fig. 1-3; pl. 22, fig. 22.

Zygodiscus nanus GARTNER, 1968, p. 33, pl. 14, fig. 17, pl. 18, fig. 12-14.

Remarks.—Recognized only in proximal views, this form has an outer and secondary cycle, each containing 28 to 36 radial elements.

Size.—Maximum diameter, 5.2 μ.

Types.—Hypotypes, UI-H-3355, UI-H-3356, UI-H-3596, UI-H-3597.

Occurrence.—Localities and samples, *B-8, B-22, LW-2, LW-3, LW-4, N-100, PB-50, PH-8, PS-1, S-10, S-11, WR, 42a.* Known range, Turonian-Maastrichtian.

Illustrations.—Plate 34, figures 9-10; 9, UI-H-3596, *WR*, proximal, ×10,800; 10, UI-H-3597, *PB-50*, proximal, ×11,500.

ZYGODISCUS LACUNATUS Gartner

Zygodiscus lacunatus GARTNER, 1968, p. 33, pl. 17, fig. 6a-d; pl. 18, fig. 15-16; pl. 19, fig. 5a-d; pl. 23, fig. 15-16; pl. 24, fig. 3a-d.

Remarks.—This is one of the largest forms encountered in the Upper Cretaceous. A large number of elements (60 to 80) forms the rim cycle.

Size.—Maximum diameter, 13 μ.

Types.—Hypotypes, UI-H-3340, UI-H-3341.

Occurrence.—Localities and samples, *B-8, LW-1, PB-50, S-1, S-3, S-10, S-11.* Known range, Santonian-Campanian.

Illustrations.—Plate 34, figures 11-12; 11, UI-H-3340, *S-11*, distal, ×4850; 12, UI-H-3341, *PB-50*, distal, ×5490.

ZYGODISCUS MACLEODAE Bukry, n. sp.

Description.—The smooth, elliptical outline of the rim has an eccentricity of 1.5. The rim has 26 to 30 dextrally imbricated and radially sutured elements. The central area is composed of a hollow fluted central stem and 2 round perforations that generally are not completely piercing. The perforations occur within 2 sloping rhomb-shaped elements. One diagonal of each rhomb is aligned with the long axis of the ellipse. In distal view beside the one large perforated rhomb face one side face is visible on each element. These are always symmetrically arranged, one on either side of the long axis. The rhombs commonly "appear to submerge" into the rim (sloping away from the central stem).

Remarks.—One specimen shows complete rhombs. These have a unique notch at the distal ends along the long axis of the ellipse. The "framed perforations" distinguish *Zygodiscus macleodae* from other species of the genus. *Z. macleodae* appears to have been derived from *Z. minimus* BUKRY, n. sp.

Size.—Maximum diameter, 4.1 μ.

Types.—Holotype, UI-H-3342, distal view (Pl. 35, fig. 2). Paratypes, UI-H-3343 through UI-H-3345.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-3, LW-4.* Known range, Campanian.

Illustrations.—Plate 35, figures 1-3; 1, UI-H-3344, *LW-4*, distal, ×16,400; 2, holotype, UI-H-3342, *LW-4*, distal, ×14,800; 3, UI-H-3345, *LW-4*, distal, ×13,900.

ZYGODISCUS? MEGAMARGINATUS Bukry, n. sp.

Description.—This is an elliptical form with eccentricity of 1.5. The single cycle of 44 rim elements imbricates dextrally. In distal view the main suture line of each element is inclined counterclockwise. However, the margin of each element becomes strongly clockwise near the axial slit at the center of the coccolith. Traces of element sutures on the proximal side can be seen to be slightly scalloped and to incline counterclockwise in proximal view. Measured across the short axis of the ellipse the central area slit occupies only 7 percent of the total width.

Remarks.—The reduction of the central area to an elongate slit makes this a unique form. Zygodiscids are the simplest group, with respect to central area, which has similarly oriented elements in a broad rim.

Size.—Maximum diameter, 5 μ.

Types.—Holotype, UI-H-3346, distal view (Pl. 35, fig. 4).

Occurrence.—Type stratigraphic source, Kjölby Gaard Chalk. Type locality, Kjölby Gaard, Denmark. Locality and sample, *KG-11.* Known range, Upper Maastrichtian.

Illustration.—Plate 35, figure 4, holotype, UI-H-3346, *KG-11*, distal, ×9500.

ZYGODISCUS MEUDINI Bukry, n. sp.

Description.—The outline of this species is rather circular with eccentricity of 1.2. In distal view, the rim cycle has 36 to 44 elements that incline slightly counterclockwise or radially and imbricate dextrally. The crossbar has a fluted solid stem composed of radially arranged laths. A series of large blocks within the outer rim form an irregular, central area lining. The perforations flanking the crossbar are small or filled-in. In proximal view the outer rim is inclined strongly counterclockwise. The inner cycle is radial and dextrally imbricated. The rim count (32 to 38) is slightly less than the outer rim.

In proximal view the crossbar is distinctively constructed. A suture along the short axis of the ellipse (lath-shaped elements meets the suture at about 45° angles) and a less distinct suture dividing the crossbar along the trace of the long axis of the ellipse. The crossbar is thus divided into 4 areas. Each area of the crossbar is made of lath-shaped elements approximately parallel to the outline of the adjacent rim. The lath sutures make a 45° angle with the short axis of the ellipse. Various amounts of perforation closing are noted in proximal view.

Remarks.—Forms with perforations completely open to completely closed were encountered in the same sample. *Zygodiscus elegans* GARTNER emended is the most comparable form. *Z. meudini* is distinguished by its central area lining cycle in distal view, smaller and less circular perforations, prominence of the radial margin of rim elements, and broader differently constructed crossbar.

Size.—Maximum diameter, 10 μ.

Types.—Holotype, UI-H-3349, distal view (Pl. 35, fig. 6). Primary paratype, UI-H-3348, proximal view (Pl. 35, fig. 8). Other paratypes, UI-H-3347, UI-H-3348, UI-H-3350.

Occurrence.—Type stratigraphic source, Craie de Meudon. Type locality, Meudon, France. Localities and samples, *B-8, B-22.* Known range, Campanian.

Illustrations.—Plate 35, figures 5-8; 5, UI-H-3347, *B-8*, distal, ×5810; 6, holotype, UI-H-3349, *B-8*, distal, ×5810; 7, UI-H-3350, *B-8*, proximal, ×6140; 8, UI-H-3348, *B-8*, proximal, ×4800.

ZYGODISCUS MINIMUS Bukry, n. sp.

Description.—The elliptical rim cycle of this small species is composed of 22 to 30 dextrally imbricated elements inclined clockwise. Rim margins are smooth or serrate. The eccentricity of the outline varies from 1.3 to 1.8. The central area is filled by a multi-element central stem flanked by 2 large, flat elements which completely occupy the remaining area.

Remarks.—The 2 large central area elements can be enlarged and raised to suggest affinity to *Zygodiscus macleodae* Bukry, n. sp.

Size.—Maximum diameter, 4.8 μ.

Types.—Holotype, UI-H-3354, distal view (Pl. 35, fig. 10). Paratypes, UI-H-3351, UI-H-3353.

Occurrence.—Type stratigraphic source, lower Austin Chalk. Type locality, Farm Road 1382, South Dallas County, Texas. Localities and samples, *LW-1, LW-2, PB-50, PS-1, PSA, PT-6, Q-6, S-3, S-4, S-11, SF-10, SF-11, WR, 42a.* Known range, Santonian.

Illustrations.—Plate 35, figures 9-11; 9, UI-H-3627, *PSA*, distal, ×12,100; 10, UI-H-3354, *LW-2*, distal, ×13,500; 11, UI-H-3353, *42a*, distal, ×14,400.

ZYGODISCUS? PHACELOSUS (Stover), Bukry, n. comb.

Tranolithus phacelosus Stover, 1966, p. 146, pl. 4, figs. 23-25; pl. 9, fig. 7.

Remarks.—The slightly serrate outline of this elliptical coccolith has eccentricity of 1.4 to 1.5. In distal view the rim cycle is composed of 40 to 43 dextrally imbricated elements with the main sutures inclining slightly counterclockwise and the inner margin sutures inclining strongly clockwise. The central area occupies 59 to 63 percent of the coccolith length. Four large rectangular blocks occupy the quadrants of the central area. One margin of each block is aligned with the long axis of the ellipse. Two diametrically opposed blocks are usually smaller, so that sutures aligned with the short axis of the ellipse are offset. A perforation or depression may occur at ends of the central area between the blocks and the inner rim margin, along the long axis of the ellipse. Gross modification of *Zygodiscus* crossbars would account for the distinctive central area structure. Some specimens show a small stem at the center.

Size.—Maximum diameter, 8.1 μ.

Types.—Hypotypes, UI-H-2890 through UI-H-2894.

Occurrence.—Localities and samples, *LW-1, LW-2, PH-8, PS-1, PSA, S-1, S-3, S-11, WR, 42a.* Known range, Santonian.

Illustration.—Plate 35, figure 12, UI-H-3628, *S-3*, distal, ×7130.

ZYGODISCUS sp. aff. Z. SIGMOIDES Bramlette & Sullivan

Zygodiscus sigmoides Bramlette & Sullivan, 1961, p. 149, pl. 4, fig. 11a-e.——Bramlette & Martini, 1964, p. 303, pl. 4, fig. 3-5.

Remarks.—*Zygodiscus sigmoides* was described originally from the Paleocene of California and later recorded in the type Danian. Light-microscope illustrations show a narrow rim, sigmoid crossbar, and short, solid stem. The specimens here attributed to *Z. sigmoides* are from Campanian deposits of Texas and Germany. The electron micrographs show dominant elements in the sigmoid crossbar, in continuity with the solid stem. These specimens have broader rims than the holotype. Rim counts of 31 and 34 elements are noted. The eccentricities of the elliptical outlines are 1.4 and 1.5. The holotype illustration shows no rim elements; the eccentricity is 1.3.

Size.—Maximum diameter, 7.7 μ.

Figured specimens.—UI-H-3357, UI-H-3358.

Occurrence.—Localities and samples, *B-22, LW-4.* Known range, Campanian-Paleocene.

Illustrations.—Plate 36, figures 1-2; 1, UI-H-3357, *LW-4*, distal, ×10,100; 2, UI-H-3358, *B-22*, distal, ×7300.

ZYGODISCUS SISYPHUS Gartner, emend. Bukry

Zygodiscus sisyphus Gartner, 1968, p. 34, pl. 14, fig. 19; pl. 18, fig. 17-19; pl. 21, fig. 6a-c; pl. 22, fig. 5-6; pl. 23, fig. 17-18; pl. 25, fig. 19-22; pl. 26, fig. 6a-d.

Remarks.—The "hopeless diversity of forms" characterizing this group includes smooth and serrate forms with 30 to 35 rim elements according to the original description. This group is distinguished here, by a slightly narrower rim than *Zygodiscus elegans* Gartner by the inclusion of serrate forms and by extending the rim counts to forms with about 20 to 35 elements. In proximal view the crossbar is composed of 2 rows of elements with a common boundary along the short axis of the ellipse. The stem is circular and usually hollow.

Size.—Maximum diameter, 5.9 μ.

Types.—Hypotypes, UI-H-3604 through UI-H-3607.

Occurrence.—Localities and samples, *LW-4, N-0, PT-6, S-1, S-3, S-4, S-9, S-11, WR.* Known range, Coniacian-Campanian.

Illustrations.—Plate 36, figures 3-4; 3, UI-H-3605, *PT-6*, distal, ×11,500; 4, UI-H-3607, *S-3*, proximal, ×7600.

ZYGODISCUS SLAUGHTERI Bukry, n. sp.

Description.—This is an elliptical coccolith with eccentricity of 1.2 to 1.5. It has 2 rim cycles visible in proximal view. The outer cycle is composed of 30 to 49 (usually 35 to 45) elements which imbricate dextrally and incline counterclockwise. The inner cycle is also dextrally imbricated but the sutures are radial. Rim counts here are 30 to 50. The outline is smooth, with only a few slightly serrate forms noted. The outer cycle surface slopes adcentrally, while the inner cycle slopes abcentrally. There are 2 styles of crossbars, both composed of a large number of tiny elements. One type has a uniform crossbar of moderate width with essentially parallel margins. The second, and more common type, has a radially arranged center (base of a stem) which has a diameter greater than the width of the associated crossbar. While the 2 flanking perforations which compose the rest of the central area are consistently open, most specimens have partial or complete closing of the perforations on the distal surface of the coccolith.

Remarks.—This form was not recognized in distal view. Specimens from the Taylor Marl show steplike ridges on the rim elements.

Size.—Maximum diameter, 8.2 μ.

Types.—Holotype, UI-H-3360, proximal view (Pl. 36, fig. 6). Paratypes, UI-H-3359, UI-H-3361.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *ALB, B-22, LW-1, LW-2, LW-3, LW-4, N-100, PB-50, PH-8.* Known range, Albian-Campanian.

Illustrations.—Plate 36, figures 5-6; 5, UI-H-3359, *LW-4,* proximal, ×4550; 6, holotype, UI-H-3360, *LW-4,* proximal, ×8080.

ZYGODISCUS THETA (Black) Bukry, n. comb.

Discolithus theta BLACK in BLACK & BARNES, 1959, p. 327, pl. 12, fig. 1.

Remarks.—The rim and crossbar are narrow on this large form, resulting in very large openings. Eccentricities of the elliptical outline vary from 1.2 to 1.5. In distal view the 32 to 46 rim elements imbricate dextrally and incline radially. A long slender solid stem rises from the center of the crossbar. In proximal view a secondary cycle of smaller elements with a similar count rests on the distal rim. Many specimens from the Taylor Marl have deep indentations in the rim elements flanking the crossbar. This dimpling occurs in a number of taxa from the Taylor Marl.

Size.—Maximum diameter, 10.3 μ.

Types.—Hypotypes, UI-H-3362 through UI-H-3365.

Occurrence.—Localities and samples, *LW-4, Q-5, Q-6, S-10.* Known range, Upper Cenomanian-Campanian.

Illustrations.—Plate 36, figures 7-8; 7, UI-H-3362, *LW-4,* distal, ×5400; 8, UI-H-3364, *Q-3,* proximal, ×9400.

Family BRAARUDOSPHAERACEAE Deflandre, 1947

Genus BRAARUDOSPHAERA Deflandre, 1947

BRAARUDOSPHAERA AFRICANA Stradner

Braarudosphaera sp. NOËL, 1958, p. 189, fig. 47.

Braarudosphaera africana STRADNER, 1961, p. 82, fig. 44.——STRADNER & PAPP, 1961, p. 118, pl. 37, fig. 4a-b, text-fig. 12,2.

Braarudosphaera bigelowi (Gran and Braarud), GARTNER, 1968, *(partim),* p. 45, pl. 4, fig. 5.

Remarks.—STRADNER's original illustration of this form shows that it differs from *Braarudosphaera bigelowi* by having more equilateral elements and by having an indentation in each side of the pentagonal outline. The apex of these indentations occurs at the juncture of each element suture with the periphery. The maximum supplementary angles of these indentations on STRADNER's figures are 39° and 34°. GARTNER's figure has a maximum angle of 33°. The specimens figured here have maximum angles of 34° and 23°. Most Cretaceous braarudosphaerids observed are rather poorly preserved and less regularly symmetrical than later forms.

Size.—Maximum diameter, 11.7 μ.

Types.—Hypotypes, UI-H-2925, UI-H-2926.

Occurrence.—*B-8, LW-2.* Known range, Albian-Eocene.

Illustrations.—Plate 36, figures 9-10; 9, UI-H-2926, *B-8,* distal, ×4320; 10, UI-H-2925, *LW-2,* distal, ×6460.

BRAARUDOSPHAERA BIGELOWI BIGELOWI (Gran and Braarud) Deflandre

Remarks.—This simple 5-element pentalith is reported in most samples studied from Albian to the present (for extensive synonomy see STRADNER & PAPP 1961). Many Cretaceous specimens show blocky overgrowths or surface depressions. Tertiary forms are generally more regular and featureless.

Size.—Maximum diameter, 10 μ.

Types.—Hypotypes, UI-H-2927, UI-H-2929, UI-H-2930.

Occurrence.—Localities and samples, *B-8, LW-2, LW-3, S-10, S-11, SF-11, WR, 42a.* Known range, Albian-Recent.

Illustrations.—Plate 36, figures 11-12; 11, UI-H-2929, *S-10,* distal, ×6140; 12, UI-H-2928, *LW-2,* distal, ×5490.

BRAARUDOSPHAERA BIGELOWI IMBRICATA Bukry, n. ssp.

"Pentaliths of uncertain affinities," HAY & TOWE, 1962, p. 426-28, fig. 2.

Braarudosphaera bigelowi (Gran and Braarud), GARTNER, 1968, *(partim)* p. 45, pl. 19, fig. 7a-c.

Description.—The 5 pentalith elements overlap, commonly with one overlapped by both adjacent elements. The overlapping is best seen in proximal view where it is sinistral.

Remarks.—This subspecies is distinguished from *Braarudosphaera bigelowi bigelowi* (GRAN & BRAARUD) by the overlap of its elements which results in an irregular central depression.

Size.—Maximum diameter, 11.9 μ.

Types.—Holotype, UI-H-2933 (Pl. 37, fig. 2). Paratypes, UI-H-2928, UI-H-2931, UI-H-2932.

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Walnut Creek at Route 290, Austin, Texas. Localities and samples, *B-8, LW-2, 42g.* Known range, Santonian-Campanian.

Illustrations.—Plate 37, figures 1-3; 1, UI-H-2931, *LW-2,* proximal, ×5490; 2, holotype, UI-H-2933, *42g,* proximal, ×6140; 3, UI-H-2928, *LW-2,* distal, ×6460.

BRAARUDOSPHAERA sp. aff. B. DISCULA Bramlette & Riedel

Braarudosphaera discula BRAMLETTE & RIEDEL, 1954, p. 394, pl. 38, fig. 7.

Braarudosphaera cf. *B. discula* STRADNER, 1959, p. 487, fig. 64.

Braarudosphaera discula STRADNER, 1961, p. 82, fig. 42.——BRAMLETTE & SULLIVAN, 1961, p. 153, pl. 8, fig. 6a-b, 7.

Braarudosphaera cf. *B. discula* STRADNER & PAPP, 1961, p. 188, pl. 8, fig. 2a-b.——SULLIVAN, 1964, p. 39, pl. 8, fig. 1a-b, 3a-b.

Remarks.—The outline of this form is pentagonal to circular. It is distinguished from other species of *Braarudosphaera* by the element sutures meeting the periphery at the apices of the pentagon. Slightly rounded and poorly preserved specimens may mimic *B. discula,* as possibly is true here and for other reports of Mesozoic

B. discula. These forms may be transitional to the distinctly circular forms of *B. discula* in the Paleocene-Eocene, however.

Size.—Maximum diameter, 7 μ.

Figured specimen.—UI-H-2934.

Occurrence.—Locality and sample, *B-8*. Reported range, Neocomian-Eocene.

Illustration.—Plate 37, figure 4, UI-H-2934, *B-8*, proximal, ×6460.

Organ genus HEXALITHUS Gardet, 1955

HEXALITHUS GARDETAE Bukry, n. sp.

Description.—This is a very small monolamellar, subcircular shield composed of 6 elements. The interelement sutures of diametrically opposed elements are aligned. Curvature of the peripheral side of each is slightly greater than the curvature of the whole shield outline, thus producing a slightly scalloped effect.

Remarks.—Only 2 other species have been reported in this genus. *Hexalithus hexalithus* NOËL (=*H. noelae* LOEBLICH & TAPPAN has a hexagonal periphery. *H. lecalae* NOËL has a subcircular outline but is 9 μ in maximum diameter.

Size.—Maximum diameter, 1.7μ (holotype), 3μ (paratype).

Types.—Holotype, UI-H-3319 (Pl. 37, fig. 6). ?Paratype, UI-H-3320.

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Walnut Creek at Route 290, Austin, Texas. Localities and samples, *?WR, 42a*. Known range, Santonian.

Illustrations.—Plate 37, figures 5-6; 5, ?UI-H-3320, *WR*, ×11,480; 6, holotype, UI-H-3319, *42a*, ×19,200.

Organ genus HEXANGULOLITHUS Bukry, n. gen.

Description.—This small form with a rounded polygonal outline is composed of numerous overlapping planar polygonal elements. Cycle outlines are concentrically smaller toward the center of the nannofossil.

Type species.—*Hexangulolithus primus* BUKRY, n. sp.

Remarks.—This genus is similar to braarudosphaerids in being composed of polygonal laths. The high number of laths and concentric overlapped cycles distinguish this form from other braarudosphaerid genera.

HEXANGULOLITHUS PRIMUS Bukry, n. sp.

Description.—This species has a rounded polygonal outline. It has about 14 individual polygonal elements which appear to spiral dextrally. The elements have marginal angles of 110° to 118°. Assuming regular polygonal elements, the shape of individual elements is either hexagonal (120°) or pentagonal (110°). Margins of directly overlapping elements are subparallel. There are 6 such overlapping cycles arrayed about the center.

Remarks.—Like *Hexalithus* and *Tetralithus*, no living forms produce this type of coccolith and its affinities are uncertain. It is most comparable to *Braarudosphaera* which produces coccoliths composed of a cycle of polygonal elements.

Size.—Maximum diameter, 3.3 μ.

Types.—Holotype, UI-H-3321 (Pl. 37, fig. 7).

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Shook Avenue at White Rock Road, Dallas, Texas. Locality and sample, *WR*. Known range, Santonian.

Illustration.—Plate 37, figure 7, holotype, UI-H-3321, *WR*, ×???

Organ genus RUCINOLITHUS Stover, 1966

RUCINOLITHUS HAYI Stover

Rucinolithus hayi STOVER, 1966, p. 156, p. 7, fig. 21; pl. 9, fig. 22.

Remarks.—The 6 or 7 rhombic-outlined elements of the rosette imbricate dextrally.

Size.—Maximum diameter, 7.6 μ.

Types.—Hypotypes, UI-H-2995, UI-H-2996.

Occurrence.—Localities and samples, *PB-50, PH-8*. Known range, Santonian-lower Campanian.

Illustrations.—Plate 37, figures 8-9; 8, UI-H-2995, *PB-50*, ×6180; 9, UI-H-2996, *PH-8*, ×7130.

RUCINOLITHUS SUMASTROCYCLUS Bukry, n. sp.

Description.—This approximately circular form is composed of a single cycle of wedge-outlined elements and a superimposed star-shaped cycle of smaller elements. The main cycle is composed of 12, 10, 9 and 9 elements which meet a closed or slightly open center in the specimens studied. The superimposed star-shaped cycle is composed of 11, 9 and 8 narrow elements separated from each other except at the center. The rays of the smaller cycle usually lie at or near, the sutures of the larger cycle. The radius of the inner cycle is one half that of the larger cycle. No distinct rim or any second shield is apparent. The entire form is probably planar.

Remarks.—Species of *Radiolithus* and *Biantholithus* have distinct rims and lack a stellar cycle. *Rucinolithus hayi* STOVER has a serrate outline, is distinctly imbricated, and lacks the stellar cycle. *R. sumastrocyclus* is characterized by a circular outline, lack of a distinct rim, lack of distinct imbrication, and a stellar cycle of superimposed elements.

Size.—Maximum diameter, 4.4 μ.

Types.—Holotype, UI-H-2997, distal view (Pl. 37, fig. 10). Paratypes, UI-H-2998, UI-H-2999.

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-2, LW-3*. Known range, Santonian.

Illustration.—Plate 37, figure 10, holotype, UI-H-2997, *LW-2*, distal, ×10,100.

Organ genus TETRALITHUS Gardet, 1955

TETRALITHUS OBSCURUS Deflandre

Tetralithus obscurus DEFLANDRE, 1959, p. 138, fig. 26-29.——MARTINI, 1961, p. 3, pl. 1, fig. 2.——BRAMLETTE & MARTINI, 1964, p. 320, pl. 4, fig. 26-28.

Size.—Maximum diameter, 6.3 μ.

Types.—Hypotypes, UI-H-3315, UI-H-3316.

Occurrence.—Locality and sample, *B-8*. Known range, Coniacian-Maastrichtian.

Illustrations.—Plate 37, figures 11-12; 11, UI-H-3315, *B-8*, ×9500; 12, UI-H-3316, *B-8*, ×8550.

TETRALITHUS PYRAMIDUS Gardet

Tetralithus pyramidus GARDET, 1955, p. 521, pl. 7, fig. 66.——STRADNER, 1961, p. 83, fig. 90-91.——MARTINI, 1961, pl. 1, fig. 1.——STRADNER & PAPP, 1961, p. 123, pl. 40, fig. 12a-b; text-fig. 13/1.——STRADNER, 1963, pl. 6, fig. 3.

Size.—Maximum diameter, 3.9 μ.

Hypotypes.—UI-H-3317.

Occurrence.—Locality and sample, *B-8*. Known range, Campanian-?Miocene.

Illustration.—Plate 38, figure 1, UI-H-3317, *B-8*, ×12,800.

TETRALITHUS QUADRATUS Stradner

Tetralithus quadratus STRADNER, 1961, p. 86, fig. 92.

Remarks.—This form was first described from the Paleocene of Austria.

Size.—Maximum diameter, 3.3 μ.

Hypotype.—UI-H-3318.

Occurrence.—Locality and sample, *LW-1*. Known range, Santonian-Paleocene.

Illustration.—Plate 38, figure 2, UI-H-3318, *LW-1*, ×12,000.

Family CALCIOSOLENACEAE Kamptner, 1937

Genus ANOPLOSOLENIA Deflandre, 1952

ANOPLOSOLENIA BRASILIENSIS (Lohmann) Deflandre

Cylindrotheca brasiliensis LOHMANN, 1919, p. 187, text-fig. 56.

Anoplosolenia brasiliensis (Lohmann) DEFLANDRE, 1952, p. 458, fig. 3, 5, 6d-e.

"*Calciosolenidae* du type a lames alternes" DEFLANDRE & FERT, 1953, p. 308, pl. 3.——DEFLANDRE & FERT, 1954, p. 164, pl. 7, fig. 6, 8-9.

Anoplosolenia brasilensis (Lohmann) HALLADAL & MARKALI, 1955, p. 14, pl. 16, fig. 1-5.

Scapholithus sp. Deflandre, COHEN, 1965, p. 24, pl. 25, fig. d.

Remarks.—The rhombic frame of the specimen figured has a small angle of 46°. Electron micrograph figures of living specimens and others from ocean-bottom samples have small angles of 35°, 38°, and 41°. The approximately 20 alternating crossbars in living forms make angles of 75°, 78°, and 81° with the frame. The Taylor Marl form makes a 75° angle. COHEN's illustration (pl. 25, fig. d) shows the monoserial crossbars are composed of 2 to 5 elements. HALLDAL & MARKALI's figure (pl. 16, fig. 4) shows a 2-element structure for each crossbar. The specimen figured here has a single element composing each crossbar. Though DEFLANDRE suggested referring all fossil Calciosolenaceae to organ genus *Scapholithus*, the comparison of this fossil form to *Anoplosolenia brasiliensis* is so close that it seems inappropriate to disassociate it.

Size.—Maximum diameter, 4.1 μ.

Hypotypes.—UI-H-2935, UI-H-2936.

Occurrence.—Locality and sample, *LW-4*. Known range, Campanian-Recent.

Illustration.—Plate 38, figure 3, UI-H-2936, *LW-4*, proximal, ×16,400.

Genus SCAPHOLITHUS Deflandre, 1954

SCAPHOLITHUS DUBIUS Bukry, n. sp.

Description.—The rhombic frame of this form has a small angle of 30°. Crossbars are regularly spaced and are composed of either 1 or 2 elements. Crossbars make an angle of 80° with the "long" side of the frame and 73° with the "short" side. A complete specimen has about 17 crossbars.

Remarks.—This form is distinguished from *Scapholithus fossilis* by having a definite rhombic outline with a larger small angle, and a narrower frame and wider central area. *S. fossilis* is notably elongate with a broad frame. *Anoplosolenia brasiliensis* has a similar rhombic outline but the crossbars fail to cross the central area completely. This is the *alternans* type of crossbar of DEFLANDRE. *S. dubius* has *scalae*-type crossbars. Though an incomplete specimen, all of the generic characters of *Scapholithus* are observable.

Size.—Maximum length, 5μ (projected diagonal).

Types.—Holotype, UI-H-2937, proximal view (Pl. 38, fig. 4).

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4*. Known range, Campanian.

Illustration.—Plate 38, figure 4, holotype, UI-H-2937, *LW-4*, proximal, ×13,500.

SCAPHOLITHUS FOSSILIS Deflandre

Scapholithus fossilis DEFLANDRE in DEFLANDRE & FERT, 1954, p. 51, pl. 8, fig. 12, 16-17.——COHEN, 1964, p. 244, pl. 3, fig. 4a-d, pl. 4, fig. 2a.——MANIVIT, 1965, p. 193, pl. 1, fig. 8.

Scapholithus sp. COHEN, 1965, p. 340, pl. 2.

Scapholithus sp. GARTNER, 1968, p. 122, pl. 7, fig. 4a-c.

Remarks.—This form has a very elongate rounded rhomb-shaped frame made of numerous elements, which are observed in Recent Calciosolenaceae (HALLDAL & MARKALI, 1955), but not in fossil forms previously. The small angle of the frame in specimens described here is 15°, 17°, 18°, 18°, 19°, and 19°. The figures compare to 19° measured from GARTNER's Maastrichtian specimen; and 24°, 24°, and 21° measured from Adriatic bottom samples of COHEN. DEFLANDRE's original syntype suite material from Mio-Pliocene deposits have small angles of 20° and 25°. Only the figures by COHEN reveal the crossbars. His specimens have about 14 and 20 single-element crossbars. Counts from specimens studied here are in the same range. The crossbars are single or composed of 2 elements. Some specimens have a small rudder-like projection at one end of the frame.

Since DEFLANDRE did not designate a holotype, his pl. 8, fig. 12 (in DEFLANDRE & FERT 1954) is designated as lectotype for *Scapholithus fossilis*; pl. 8, fig. 16-17, are designated paralectotypes.

Size.—Maximum diameter, 6.1μ (diagonal).

Hypotypes.—UI-H-2938 through UI-H-2941.

Occurrence.—Localities and samples, *B-22, LW-4.* Known range, Albian-Pliocene.

Illustrations.—Plate 38, figures 5-8; 5, UI-H-2939, *LW-4,* distal, ×16,400; 6, UI-H-2941, *LW-4,* distal, ×9500; 7, UI-H-2940, *LW-4,* proximal, ×18,200; 8, UI-H-2938, *B-22,* proximal, ×9370.

SCAPHOLITHUS STEGNUS Bukry, n. sp.

Description.—This compact form has an elongate rhombic outline. The small angle of the rhomb is 32°. The laminated frame is so broad that the central area is constricted to a small opening with only 2 crossbars. About 20 elements compose the frame.

Remarks.—A broad frame and small central opening distinguish this form from other *Scapholithus* species.

Size.—Maximum diameter, 4.0 μ (diagonal).

Holotype.—UI-H-2942, distal view (Pl. 38, fig. 9).

Occurrence.—Type stratigraphic source, upper Austin Chalk. Type locality, Shook Avenue at White Rock Road, Dallas, Texas. Locality and sample, *WR.* Known range, Santonian.

Illustration.—Plate 38, figure 9, holotype, UI-H-2942, *WR,* distal, ×16,400.

Family DISCOASTERACEAE Tan, 1927

Organ genus DISCOASTER Tan, 1927

DISCOASTER? HAYI, Bukry, n. sp.

Description.—This small species has 5 thin straight tapering rays, which are single calcite elements that flare out on one side to form a disc about the center of the fossil. A short stalk at the center is formed by 5 small rods which extend from the interray disc areas. The 5 ray-elements imbricate sinistrally.

Remarks.—The appearance of a central disc with 5 straight radial rays extending from it and through it provides a distinctive outline for this form. Small size and 5 interray rods also serve to distinguish *Discoaster? hayi* from other discoasters. The closest comparable form is *Discoaster lodoensis* BRAMLETTE & RIEDEL, a 7-ray form which also has prominent ribs at one side of each ray element. Other 5-ray species with prominent central discs all lack these prominent ribs.

Size.—Maximum diameter, 7.8 μ (holotype).

Types.—Holotype, UI-H-2915, distal view (Pl. 38, fig. 12). Paratypes, UI-H-2914, UI-H-2916, UI-H-2917.

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Localities and samples, *LW-3, LW-4.* Known range, Campanian.

Illustrations.—Plate 38, figures 10-12; 10, UI-H-2914, *LW-4,* distal, ×7200; 11, UI-H-2916, *LW-4,* distal, ×8080; 12, holotype, *LW-4,* UI-H-2915, distal, ×5700.

DISCOASTER? NOELAE Bukry, n. sp.

Description.—This regular, 8-rayed discoaster has 8 straight median ribs which stand out in strong relief above the flanking ray areas. The ribs begin at tips of the rays and run directly to the slender cylindrical central stalk. The 8 rays have a free margin for only about half of the length of each rib. Interrib notches in the margin occur half-way between the ribs and produce a symmetric outline.

Remarks.—This form bears closest resemblance to the Paleogene *Discoaster lodoensis* BRAMLETTE & SULLIVAN group figured by STRADNER & PAPP (1961). Both forms have ribs along each ray which terminate at a central stalk. However, none of STRADNER's variations includes an 8-rayed form with very short free rays. Most distinctly, strong curvature of the rib in each ray is characteristic of *D. lodoensis.* Also, this rib always runs along one side of each ray. *Discoaster? noelae* ribs are practically straight and run along the center of each ray. Since discoasters are rarely reported in pre-Tertiary samples, this may be a forerunner of the *D. lodoensis* group.

Size.—Maximum diameter, 6.3 μ.

Holotype—UI-H-2918, distal view (Pl. 39, fig. 1).

Occurrence.—Type stratigraphic source, lower Taylor Marl. Type locality, Lake Waxahachie, Ellis County, Texas. Locality and sample, *LW-4.* Known range, Campanian.

Illustration.—Plate 39, figure 1, holotype, UI-H-2918, *LW-4,* distal, ×9030.

Organ genus MARTHASTERITES Deflandre, 1959

MARTHASTERITES FURCATUS FURCATUS (Deflandre) Deflandre

Discoaster(?) furcatus DEFLANDRE, 1954, p. 168, pl. 13, fig. 14. ——STRADNER, 1958, p. 181, text-fig. 7.

Marthasterites furcatus (Deflandre) DEFLANDRE, 1959, p. 139, pl. 2, fig. 3-12, pl. 3, fig. 1, 5.

Discoaster furcatus MARTINI, 1960, pl. 10, fig. 33.

Marthasterities furcatus MARTINI, 1961, p. 15, pl. 3, fig. 3.—— STRADNER, 1961, p. 83, text-figs. 82-83.——STRADNER, 1963, pl. 2, fig. 11-11a.

Remarks.—This form has been recorded as common only in Santonian to lower Campanian samples. MARTINI reported it as reworked specimens in the Oligocene.

Size.—Maximum diameter, 8.7 μ.

Hypotypes.—UI-H-2899 through UI-H-2901.

Occurrence.—Localities and samples, *LW-3, LW-4, N-100, Q-5, S-10, S-11.* Known range, Santonian-Campanian.

Illustrations.—Plate 39, figures 2-4; 2, UI-H-2901, *LW-4,* ×7600. UI-H-2899, *LW-4,* ×7130. UI-H-2900, *LW-4,* ×5490.

MARTHASTERITES FURCATUS CRASSUS Deflandre

Marthasterites furcatus (Deflandre) var. *crassus* DEFLANDRE, 1959, p. 139, pl. 2, fig. 17; pl. 3, fig. 3, 4.——GARTNER, 1968, p. 42, pl. 21, fig. 16.

Remarks.—This short, stubby, triradiate nannofossil was found at only one sample locality.

Size.—Maximum diameter, 6.7 μ.

Hypotype.—UI-H-2902.

Occurrence.—Localities and samples, *LW-3, LW-4.* Known range, Santonian-Campanian.

Illustration.—Plate 39, figure 5, UI-H-2902, *LW-4,* ×8080.

MARTHASTERITES FURCATUS SIMPLEX Bukry, n. ssp.

Description.—A simple triradiate nannofossil, this form is characterized by cuplike terminations of the long rays.

Remarks.—Except for the slight flaring of the ray terminations, this subspecies is similar to *Marthasterites tribrachiatus* (Bramlette & Riedel) DEFLANDRE of the Tertiary. It lacks the widely bifurcating terminations of *M. furcatus furcatus* (Deflandre) DEFLANDRE and has proportionally longer rays than other figured subspecies. Since BURSA (1964) discovered that the living *Discoasteromonas calciferus* organisms produce triradiate, as well as discoaster-like skeletal elements, it appears that much of the variety observed in *Marthasterites* could be produced by a single species.

Size.—Maximum diameter, 5.8 μ.

Types.—Holotype, UI-H-2903 (Pl. 39, fig. 6). Paratype, UI-H-2904.

Occurrence.—Type stratigraphic source, upper Niobrara Formation. Type locality, Knox County, Nebraska. Localities and samples, *N-100, S-3.* Known range, Santonian.

Illustrations.—Plate 39, figures 6-7; 6, holotype, UI-H-2903, *N-100,* ×9550. UI-H-2904, *S-3,* ×6180.

MARTHASTERITES JUCUNDUS Deflandre

Marthasterites jucundus DEFLANDRE, 1959, p. 140, pl. 2, fig. 18-21.
Discoaster(?) furcatus STRADNER, 1959, p. 1084, text-fig. 7.
Marthasterites jucundus MARTINI, 1961, p. 16, pl. 3, fig. 32.——STRADNER & PAPP, 1961, p. 109, pl. 34, fig. 3a-b, 4a-b; text-fig. 11/2.

Remarks.—A single specimen, smaller than the originally described forms (4.5 to 8 μ) was observed from the upper Niobrara Formation.

Size.—Maximum diameter, 3.8 μ.

Hypotype.—UI-H-2905.

Occurrence.—Locality and sample, *N-100.* Known range, Santonian-middle Eocene.

Illustration.—Plate 39, figure 8, UI-H-2905, *N-100,* ×13,500.

Family MICRORHABDULACEAE Deflandre, 1959

Organ genus MICRORHABDULUS Deflandre, 1959

MICRORHABDULUS BELGICUS Hay & Towe

Microrhabdulus belgicus HAY & TOWE, 1963, p. 95, pl. 1.
Microrhabdulus margaritatus DEFLANDRE, 1963, p. 3486, fig. 12-18.
Microrhabdulus nodosus STRADNER, 1963, p. 177, pl. 4, fig. 13.
Microrhabdulus belgicus REINHARDT, 1966, p. 42, pl. 16, fig. 3.——GARTNER, 1968, p. 44, pl. 6, fig. 13a-c; pl. 10, fig. 21-23; pl. 12, fig. 13a-c; pl. 22, fig. 27.

Remarks.—This fusiform nannofossil is found with variable sizes and numbers of node-cycles ornamenting its surface. Complete specimens are quite rare, one end usually being broken. The greatest number of node-cycles observed on a fairly complete form is 14. Cycles with up to 8 or 10 nodes are observed. Doubly tapering ends of this form indicate it is not a broken stem of another coccolith.

Size.—Maximum length, 14.4 μ.

Hypotypes.—UI-H-2906 through UI-H-2908.

Occurrence.—Localities and samples, *B-8, LW-2, LW-3, LW-4, N-0, N-100, PB-50, PH-8, PS-1, PSA, PT-6, Q-5, S-1, S-3, S-4, S-10, SF-11, WR, 42a, 42g.* Known range, Turonian-lower Maastrichtian.

Illustrations.—Plate 39, figures 9-11; 9, UI-H-2907, *LW-4,* ×4320; 10, UI-H-2906, *B-8,* ×5810; 11, UI-H-2908, *LW-4,* ×4520.

GENERA INCERTAE SEDIS

Form genus LITHRAPHIDITES Deflandre, 1963

LITHRAPHIDITES CARNIOLENSIS Deflandre

Lithraphidites carniolensis DEFLANDRE, 1963, p. 3486, fig. 1-8.——MANIVIT, 1965, p. 194, pl. 2, fig. 19.——GARTNER, 1968, p. 43, pl. 5, fig. 4; pl. 6, fig. 8a-b; pl. 10, fig. 16-17; pl. 12, fig. 8a-c; pl. 22, fig. 24-25; pl. 25, fig. 9.

Remarks.—Though it is commonly not apparent, each of the 4 keels is made of 2 appressed, bladelike elements.

Size.—Maximum length, 20 μ.

Hypotypes.—UI-H-2922 through UI-H-2924.

Occurrence.—Localities and samples, *ALB, B-8, B-22, C-4, LW-1, LW-2, LW-3, LW-4, N-100, PH-8, PS-1, PSA, PT-6, Q-2, Q-4, S-1, S-3, S-4, S-11.* Known range, Albian-Maastrichtian.

Illustrations.—Plate 39, figure 12; Plate 40, figures 1-2.——Pl. 39, fig. 12, UI-H-2923, *LW-4,* ×8080.——Pl. 40, fig. 1-2; 1, UI-H-2924, *LW-4,* ×3020; 2, UI-H-2922, *LW-4,* ×8550.

LITHRAPHIDITES GROSSOPECTINATUS Bukry, n. sp.

Description.—Each of the 4 keels are composed of 2 lamellar elements. The keels meet at 90° along a common axis. A few major teeth (about 4), truncated parallel to the central axis, form the outer margins of the keels. The toothed region of each keel does not extend to ends of the central axis.

Remarks.—In possessing a wide bluntly ending 4-keel shape, this form is similar to *Lithraphidites quadratus* BRAMLETTE & MARTINI. However, *L. grossopectinatus* has a distinct toothed keel. The bilamellar nature of the keels in this form suggests that *L. quadratus* should have the same structure.

Size.—Maximum diameter, 6.6 μ.

Types.—Holotype, UI-H-2920 (Pl. 40, fig. 3). Paratypes, UI-H-2919 and UI-H-2921.

Occurrence.—Type stratigraphic source, Kjölby Gaard chalk (11 m. below Danian). Type locality, Kjölby Gaard, Denmark. Locality and sample, *KG-11.* Known range, Maastrichtian.

Illustration.—Plate 40, figure 3, holotype, UI-H-2920, *KG-11,* ×9300.

Form genus LUCIANORHABDUS Deflandre, 1959

LUCIANORHABDUS CAYEUXI Deflandre

Lucianorhabdus cayeuxi DEFLANDRE, 1959, p. 142-143, pl. 4, fig. 11-25.——MARTINI, 1961, p. 19, pl. 4, fig. 39.——STRADNER, 1961, p. 82, text-fig. 45-48, 50.——STRADNER, 1963, p. 15, pl. 6, fig. 6-6a.——BRAMLETTE & MARTINI, 1964, p. 312, pl. 5, fig.

11-12.——STOVER, 1966, pl. 7, fig. 13-14.——GARTNER, 1968, p. 45, pl. 10, fig. 18-20; pl. 12, fig. 7a-c; pl. 16, fig. 3-4; pl. 18, fig. 3-4, pl. 20, fig. 14.

Size.—Maximum length, 19 μ.

Hypotypes.—UI-H-2943 through UI-H-2945.

Occurrence.—Localities and samples, *B-15, B-22, LW-4, PT-6, S-10, 42g.* Known range, Santonian-Maastrichtian.

Illustration.—Plate 40, figure 4, UI-H-2944, *PT-6,* ×3880.

Form genus MICULA Vekshina, 1959

MICULA DECUSSATA DECUSSATA Vekshina

Micula decussata VEKSHINA, 1959, p. 71, pl. 1, fig. 6; pl. 2, fig. 11.

Trochoaster staurophorus (Gardet) STRADNER, 1959, p. 480, fig. 49-50.

Trochoaster staurophorus (Gardet) MARTINI, 1960, p. 82, pl. 10, fig. 37.

Nannotetraster staurophorus (Gardet) MARTINI & STRADNER, 1960, p. 266, fig. 1.——STRADNER & PAPP, 1961, p. 101, pl. 31, fig. 2-4.

Micula staurophora (Gardet) STRADNER, 1963, p. 179, pl. 4, fig. 12a.——BRAMLETTE & MARTINI, 1964, p. 318, pl. 6, fig. 7-11.

Micula decussata Vekshina GARTNER, 1968, *(partim)*, p. 47, pl. 2, fig. 5 and 8; pl. 4, fig. 17; pl. 9, fig. 18; pl. 14, fig. 13; pl. 18, fig. 7; pl. 20, fig. 15.

Remarks.—A roughly circular center is seen on each of the 6 cube faces, which are concave and show concentric structure between the center and face edges. The corners of the cube may be orthogonal or slightly extended into points. GARTNER has discussed the taxonomic problems involving this form. *Micula decussata decussata* is distinguished from *M. decussata concava* (Stradner) BUKRY, n. comb., by its lack of elongate processes at the cube corners.

Size.—Maximum diameter, 6.2 μ (diagonal).

Hypotypes.—UI-H-2985 through UI-H-2989.

Occurrence.—Localities and samples, *B-8, KG-11, LW-3, LW-4, N-0, N-100, PSA, PT-6, S-4, S-11.* Known range, Santonian-Maastrichtian.

Illustrations.—Plate 40, figures 5-6; 5, UI-H-2988, *LW-3,* ×10,400; 6, UI-H-2986, *LW-4,* ×8760.

MICULA DECUSSATA CONCAVA (Stradner) Bukry, n. comb.

Nannotetraster concavus STRADNER in MARTINI & STRADNER, 1960, p. 269, fig. 18a-d.——STRADNER, 1961, p. 83, fig. 66-69.——STRADNER & PAPP, 1961, p. 102, pl. 31, fig. 1a-d; text-fig. 10-1, 19-1 to 4.

Micula staurophora (Gardet) STRADNER *(partim)*, 1963, p. 179, pl. 4, fig. 12b-c.

Micula decussata Vekshina GARTNER, 1968 *(partim)*, p. 47, pl. 2, fig. 6-7; pl. 9, fig. 19-20.

Remarks.—Structure of this form is like that of *Micula decussata decussata.* It is distinguished by the long processes at corners of the cube.

Size.—Maximum diameter, 15.6 μ (diagonal).

Hypotypes.—UI-H-2978 through UI-H-2984.

Occurrence.—Localities and samples, *LW-4, N-100, S-10, WR.* Known range, Neocomian-Maastrichtian.

Illustrations.—Plate 40, figures 7-8; 7, UI-H-2983, *N-100,* ×9030; UI-H-3629, *LW-4,* ×6650.

Form genus NANNOCONUS Kamptner, 1931

NANNOCONUS FARINACCAE Bukry, n. sp.

Description.—This small nannoconid has an oval to beehive-shaped outline in axial section. The axis is flanked on either side in section by 11 to 13 wedges. The axial canal is cylindrical and relatively narrow. Ratios of the maximum external diameter to maximum internal diameter for all specimens studied are approximately 5. In external view the wedge-shaped elements forming the wall are arranged in spiral rows that make an angle of 45° with the central axis. The wedges at the axial ends are only apparently larger because they are viewed on a different element face.

Remarks.—None of the previously illustrated nannoconids (mostly by sketches from thin sections) show this combination of features. Because of funnel-like openings at ends of the central axis and level of axial sections, thin-sectioned specimens fail to show the axial end wedges. Electron micrographs of free specimens show such features. This species is distinguished from the comparable *Nannoconus bucheri* BRÖNNIMANN by its larger internal-external diameter ratio. The holotype and paratype illustrations of that species show a ratio of only 2.5.

Size.—Maximum diameter, 6μ. Maximum length, 8μ.

Types.—Holotype, UI-H-2992, axial section (Pl. 40, fig. 9). Paratypes, UI-H-2990, UI-H-2991, UI-H-2993.

Occurrence.—Type stratigraphic source, mid-Santonian marl. Type locality, Saintes, France. Locality and sample, *SF-11.* Known range, Santonian.

Illustrations.—Plate 40, figures 9-12; 9, holotype, UI-H-2992, *SF-11,* axial section, ×6650; 10, UI-H-2991, *SF-11,* axial section, ×5810; 11, UI-H-2993, *SF-11,* exterior, ×4100; 12, UI-H-2990, *SF-11,* axial section, ×5810.

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APPENDIX 1. FIRST OCCURRENCES OF COCCOLITH SPECIES IN SAMPLES STUDIED AND NOT REPORTED FROM OLDER DEPOSITS IN LITERATURE

Sample	First occurrences	Total species	Total negatives
DALLAS, TEXAS, AREA			
LW-4	28	103	1,115
LW-3	7	42	110
LW-2	1	38	155
LW-1	1	37	140
PB-50	0	41	135
WR	5	52	210
PH-8	3	32	75
PT-6	0	35	80
PS-1	0	27	105
S-11	4	52	170
S-10	3	36	90
PSA	1	36	90
S-6	1	13	20
S-4	0	39	140
S-3	9	50	185
Q-6	2	24	125
S-2	0	14	35
S-1	11	38	120
Q-2	2	4	40
EUROPE			
KG-11	3	16	40
B-8	4	63	370
F-14	0	10	40
B-22	9	46	385
B-15	1	3	170
SF-10	0	9	45
SF-11	2	21	180
ALB	12	16	140
NEBRASKA			
N-11+8	0	6	15
N-100	5	51	245
N-0	4	14	35
TEXAS			
42g	1	18	25
42a	3	44	210
C-4	2	7	30

APPENDIX 2. CAMPANIAN FIRST OCCURRENCES OF COCCOLITH SPECIES NOT REPORTED TO HAVE EARLIER FIRST OCCURRENCES

[Asterisk indicates BUKRY, n. sp. or n. ssp.]

TEXAS

Anoplosolenia brasiliensis
**Arkhangelskiella specillata ethmopora*
**Broinsonia dentata*
**B.? ethmoquadrata*
**B. handfieldii*
**B.? staytonae*
**Chiastozygus garrisonii*
**Corollithion ellipticum*
**Cretarhabdus crenulatus hansmanii*
Cribrosphaera pelta
**Cyclagelosphaera baticlypeata*
**C. specioclypeata*
**Cyclococcolithus? waxahachia*
**Cylindralithus sculptus*
**Discoaster? hayi*
**D.? noelae*
**Discolithina? porosuturalis*
**Gartnerago costatum porolatum*
**G. zipperum*
**Heteromarginatus wallacei*
**Kamptnerius percivalii*
**Marthasterites furcatus crassus*
Parhabdolithus regularis
**Percivalia pontilitha*
P. porosa
**Pontilithus complexus*
**Scapholithus dubius*
**Vagalapilla dentata dentata*
**V. dentata aperta*
**V. dorfii*
**Watznaueria biporta*
**W. porta*
**W. virginica*
**Zygodiscus macleodae*

EUROPE

**Angulofenestrellithus synderi*
Arkhangelskiella cymbiformis
**Discolithina? furlongii*
**D.? hallii*
**D.? pagei*
D.? polygonatus
**Gartnerago* sp.
**Prediscosphaera cretacea lata*
**P. germanica*
**Similicoronilithus primus*
Tetralithus pyramidus
**Vagalapilla compacta integra*
**Watznaueria? prolongata*
**Zygodiscus meudini*

EUROPE AND TEXAS

**Cretarhabdus multicavus*
**Ethmorhabdus camaratus*
Zygodiscus sp. aff. *Z. sigmoides*

APPENDIX 3. SANTONIAN FIRST OCCURRENCES OF COCCOLITH SPECIES NOT REPORTED TO HAVE EARLIER FIRST OCCURRENCES

[Asterisk indicates BUKRY, n. sp. or n. ssp.]

TEXAS (and NEBRASKA)

Amphizygus brooksii nanus
A. papillatus
Bidiscus cruciatus multicruciatus
B. monocavus
Biscutum asymmetricum
Braarudosphaera bigelowi imbricata
Broinsonia bevieri
B. furtiva
B.? orthocancellata
Chiastozygus bifarius
C. disgregatus
C. interruptus
C. planus
C. propagulis
C. synquadriperforatus
Cribrosphaera laughtoni
Cyclagelosphaera? chronolitha
C. rotaclypeata
Cylindralithus asymmetricus
C. biarcus
C. coronatus
C. nudus
Gartnerago costatum costatum
Hexalithus gardetae
Hexangulolithus primus
Marthasterites furcatus simplex
M. juncundus
Parhabdolithus fischeri
Podorhabdus granulatus
P. quadriperforatus
P. reinhardtii
Prediscosphaera cretacea ponticula
P. honjoi
Rucinolithus hayi
R. sumastrocyclus
Scapholithus stegnus
Tetralithus quadratus
Vagalapilla aachena
V. compacta compacta
V. imbricata elongata
Watznaueria mastersii
W. oblonga
W. ovata
W. quadriradiata
Zygodiscus biclavatus
Z. biperforatus
Z. compactus
Z. deflandrei
Z. lacunatus
Z. phacelosus

EUROPE

Nannoconus farinaccae

EUROPE and TEXAS

Amphizygus brooksii brooksii
A. minimus
Bidiscus cruciatus cruciatus
Eiffellithus augustus
Zygodiscus minimus

APPENDIX 4. SPECIES MOST COMMONLY PRESENT IN SANTONIAN-CAMPANIAN SAMPLES

[Asterisk indicates BUKRY, n. sp. or n. ssp.]

This is a *selected* list of species which are encountered most commonly in Santonian-Campanian samples. "Most commonly present" is based on the occurrence in 8 or more stratigraphically different samples and on quantitatively larger numbers of specimens than for other species not listed.

Bidiscus cruciatus cruciatus
B. rotatorius
Biscutum asymmetricum
B. multiforme
B. testudinarium
Braarudosphaera bigelowi bigelowi
Broinsonia bevieri
Chiastozygus amphipons
C. bifarius
C. inturratus
C. plicatus
Corollithion exiguum
C. rhombicum
C. signum
Costacentrum horticum
Cretarhabdus conicus
C. crenulatus crenulatus
C. schizobrachiatus
Cribrosphaera ehrenbergi
C. laughtoni
Cylindralithus asymmetricus
C. coronatus
Eiffellithus augustus
E. turriseiffeli
Gartnerago concavum
Lithastrinus floralis
L. grilli
Lithraphidites carniolensis
Lucianorhabdus cayeuxi
Microrhabdulus belgicus
Micula decussata decussata
Parhabdolithus angustus
P. fischeri
P. granulatus
Podorhabdus dietzmanni

**P. quadriperforatus*
Prediscosphaera cretacea cretacea
P. spinosa
Stephanolithion laffittei
Vagalapilla elliptica
V. octoradiata
Watznaueria barnesae
W. paenepelagica
W.? parvidentata
**Zygodiscus compactus*
Z. elegans
**Z. minimus*
Z. phacelosus
Z. sisyphus

APPENDIX 5. NUMBER OF COCCOLITH SPECIES REPORTED IN RECENT STRATIGRAPHIC STUDIES OF UPPER CRETACEOUS COLLECTIONS

	Bramlette & Martini, 1964	Stover, 1966	Gartner, 1968	Bukry, 1969
Maastrichtian	*39* (17)	....	*40* (2)	*15* (1)
Campanian	....	*25* (3)	*54* (2)	*137* (6)
Santonian	....	*29* (2)	*41* (3)	*105* (22)
Coniacian	....	*28* (3)	....	*17* (2)
Turonian	....	*27* (5)	*18* (1)	....
Cenomanian	....	*32* (6)	....	....
Albian	....	*34* (9)	....	*13* (1)
	L	L	L & E	E

(1) Number of samples reported.
L Light microscope identifications.
E Electron microscope identifications.

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[Rejected names enclosed within square brackets.]

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PLATE 2

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FIGURE

1. *Corollithion exiguum* Stradner (p. 40).

2-4. *Corollithion rhombicum* (Stradner & Adamiker), Bukry, n. comb. (p. 41).

5-8. *Corollithion signum* Stradner (p. 41).

9-12. *Cylindralithus asymmetricus* Bukry, n. sp. (p. 42).

PLATE 20

FIGURE

1-3. *Cylindralithus biarcus* Bukry, n. sp. (p. 42).

4-6. *Cylindralithus coronatus* Bukry, n. sp. (p. 42).

7-8. *Cylindralithus nudus* Bukry, n. sp. (p. 42).

9-10. *Cylindralithus sculptus* Bukry, n. sp. (p. 43).

11-12. *Cylindralithus serratus* Bramlette & Martini (p. 43).

PLATE 21

FIGURE

1-2. *Lithastrinus floralis* Stradner (p. 43).

3-6. *Lithastrinus grilli* Stradner (p. 43).

7-11. *Stephanolithion laffittei* Noël (p. 43).

12. *Costacentrum horticum* (Stradner, Adamiker & Maresch), Bukry, n. comb. (p. 44).

PLATE 22

FIGURE

1-4. *Costacentrum horticum* (Stradner, Adamiker, & Maresch), Bukry, n. comb. (p. 44).

5-6. *Costacentrum lowei* Bukry, n. sp. (p. 44).

7-12. *Cribrosphaera ehrenbergi* Arkhangelsky (p. 44).

PLATE 23

FIGURE

1-9. *Cribrosphaera laughtoni* (Black), Bukry, n. comb. (p. 45).

10-12. *Cribrosphaera pelta* (Gartner), Bukry, n. comb. (p. 45).

PLATE 24

FIGURE

1. *Discolithina? furlongii* Bukry, n. sp. (p. 45).

2-4. *Discolithina? hallii* Bukry, n. sp. (p. 46).

5-6. *Discolithina? pagei* Bukry, n. sp. (p. 46).

7. *Discolithina? polygonata* Gorka (p. 46).

8-10. *Discolithina? porosuturalis* Bukry, n. sp. (p. 46).

11-12. *Nephrolithus gorkae* Åberg (p. 47).

PLATE 25

FIGURE

1-3. *Amphizygus brooksii brooksii* Bukry, n. sp., n. ssp. (p. 47).

4-7. *Amphizygus brooksii nanus* Bukry, n. sp., n. ssp. (p. 47).

8-10. *Amphizygus minimus* Bukry, n. sp. (p. 48).

11-12. *Amphizygus papillatus* Bukry, n. sp. (p. 48).

PLATE 26

FIGURE

1-3. *Angulofenestrellithus snyderi* Bukry, n. sp. (p. 48).

4-5. *Pontilithus obliquicancellatus* Gartner (p. 55).

6-7. *Pontilithus complexus* Bukry, n. sp. (p. 54).

8-9. *Chiastozygus amphipons* (Bramlette & Martini), Gartner (p. 49).

10-12. *Chiastozygus bifarius* Bukry, n. sp. (p. 49).

PLATE 27

FIGURE

1-4. *Chiastozygus disgregatus* (Stover), Bukry, n. comb. (p. 49).

5-6. *Chiastozygus garrisonii* Bukry, n. sp. (p. 49).

7-8. *Chiastozygus interruptus* Bukry, n. sp. (p. 50).

9-11. *Chiastozygus inturratus* (Reinhardt), Bukry, n. comb. (p. 50).

12. *Chiastozygus planus* Bukry, n. sp. (p. 50).

PLATE 28

FIGURE

1-2. *Chiastozygus planus* Bukry, n. sp. (p. 50).

3. *Chiastozygus plicatus* Gartner (p. 50).

4-5. *Chiastozygus propagulis* Bukry, n. sp. (p. 51).

6-9. *Chiastozygus synquadriperforatus* Bukry, n. sp. (p. 51).

10-12. *Eiffellithus augustus* Bukry, n. sp. (p. 51).

PLATE 29

FIGURE

1. *Eiffellithus augustus* Bukry, n. sp. (p. 51).

2-5. *Eiffellithus turriseiffeli* (Deflandre), Reinhardt (p. 52).

6-7. *Heteromarginatus wallacei* Bukry, n. sp. (p. 52).

8-11. *Parhabdolithus angustus* (Stradner), Bukry, n. comb. (p. 53).

12. *Parhabdolithus fischeri* Bukry, n. sp. (p. 53).

PLATE 30

FIGURE

1-3. *Parhabdolithus fischeri* BUKRY, n. sp. (p. 53).
4-7. *Parhabdolithus granulatus* STOVER (p. 53).
8-10. *Parhabdolithus regularis* (Gorka), BUKRY, n. comb. (p. 53).
11-12. *Percivalia pontilitha* BUKRY, n. sp. (p. 54).

PLATE 31

FIGURE

1. *Percivalia pontilitha* BUKRY, n. sp. (p. 54).
2-5. *Percivalia porosa* BUKRY, n. sp. (p. 54).
6-9. *Vagalapilla aachena* BUKRY, n. sp. (p. 55).
10-11. *Vagalapilla compacta compacta* BUKRY, n. sp., n. ssp. (p. 56).
12. *Vagalapilla compacta integra* BUKRY, n. sp., n. ssp. (p. 56).

PLATE 32

FIGURE

1-3. *Vagalapilla dentata dentata* BUKRY, n. sp., n. ssp. (p. 36).
4-6. *Vagalapilla dentata aperta* BUKRY, n. sp., n. ssp. (p. 57).
7-8. *Vagalapilla dorfii* BUKRY, n. sp. (p. 57).
9-12. *Vagalapilla elliptica* (Gartner), BUKRY, n. comb. (p. 57).

PLATE 33

FIGURE

1-2. *Vagalapilla imbricata imbricata* (Gartner), BUKRY, n. comb. (p. 57).
3-4. *Vagalapilla imbricata elongata* BUKRY, n. ssp. (p. 58).
5-7. *Vagalapilla octoradiata* (Gorka), BUKRY, n. comb. (p. 58).
8-9. *Zygodiscus acanthus* REINHARDT (p. 58).
10-11. *Zygodiscus biclavatus* BUKRY, n. sp. (p. 58).
12. *Zygodiscus biperforatus* GARTNER (p. 58).

PLATE 34

FIGURE

1-2. *Zygodiscus compactus* BUKRY, n. sp. (p. 59).
3-5. *Zygodiscus deflandrei* BUKRY, n. sp. (p. 59).
6-8. *Zygodiscus elegans* Garner, emend. BUKRY (p. 59).
9-10. *Zygodiscus fibuliformis* (Reinhardt), BUKRY, n. comb. (p. 59).
11-12. *Zygodiscus lacunatus* GARTNER (p. 60).

PLATE 35

FIGURE

1-3. *Zygodiscus macleodae* BUKRY, n. sp. (p. 60).
4. *Zygodiscus? megamarginatus* BUKRY, n. sp. (p. 60).
5-8. *Zygodiscus meudini* BUKRY, n. sp. (p. 60).
9-11. *Zygodiscus minimus* BUKRY, n. sp. (p. 61).
12. *Zygodiscus? phacelosus* (Stover), BUKRY, n. comb. (p. 61).

PLATE 36

FIGURE

1-2. *Zygodiscus* sp. *aff. Z. sigmoides* BRAMLETTE & MARTINI (p. 61).
3-4. *Zygodiscus sisyphus* Gartner, emend. BUKRY (p. 61).
5-6. *Zygodiscus slaughteri* BUKRY, n. sp. (p. 61).
7-8. *Zygodiscus theta* (Black), BUKRY, n. comb. (p. 62).
9-10. *Braarudosphaera africana* STRADNER (p. 62).
11-12. *Braarupdosphaera bigelowi bigelowi* (Gran & Braarud), DEFLANDRE (p. 62).

PLATE 37

FIGURE

1-3. *Braarudosphaera bigelowi imbricata* (Gartner), BUKRY, n. ssp. (p. 62).
4. *Braarudosphaera* sp. *aff. B. discula* BRAMLETTE & REIDEL (p. 62).
5-6. *Hexalithus gardetae* BUKRY, n. sp. (p. 63).
8-9. *Rucinolithus hayi* STOVER (p. 63).
10. *Rucinolithus sumastrocyclus* BUKRY, n. sp. (p. 63).
11-12. *Tetralithus obscurus* DEFLANDRE (p. 63).

PLATE 38

FIGURE

1. *Tetralithus pyramidus* GARDET (p. 64).
2. *Tetralithus quadratus* STRADNER (p. 64).
3. *Anoplosolenia brasiliensis* (Lohmann), DEFLANDRE (p. 64).
4. *Scapholithus dubius* BUKRY, n. sp. (p. 64).
5-8. *Scapholithus fossilis* DEFLANDRE (p. 64).
9. *Scapholithus stegnus* BUKRY, n. sp. (p. 65).
10-12. *Discoaster? hayi* BUKRY, n. sp. (p. 65).

PLATE 39

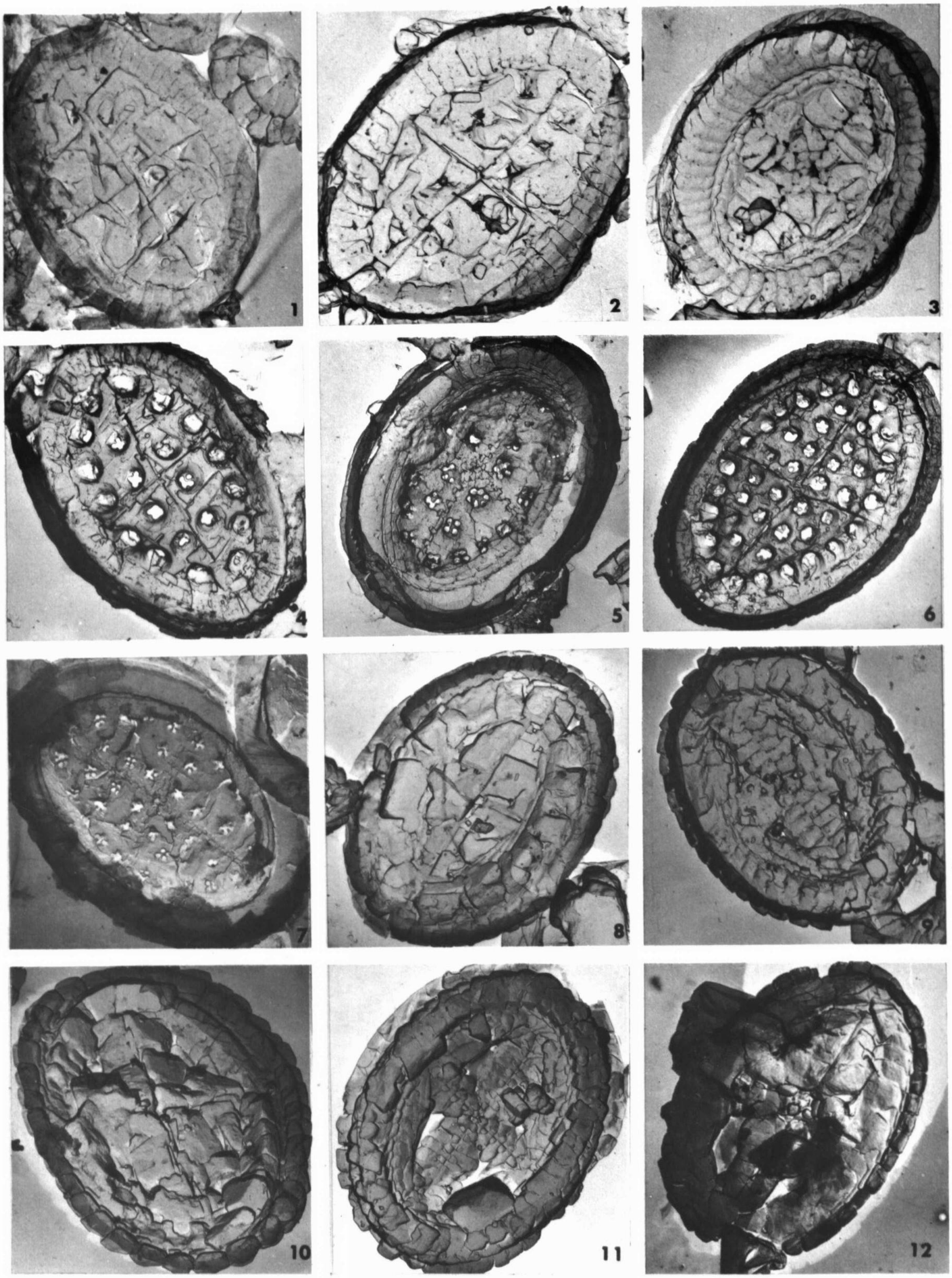
FIGURE

1. *Discoaster noelae* BUKRY, n. sp. (p. 65).
2-4. *Marthasterites furcatus furcatus* (Deflandre), DEFLANDRE (p. 65).
5. *Marthasterites furcatus crassus* DEFLANDRE (p. 65).
6-7. *Marthasterites furcatus simplex* BUKRY, n. ssp. (p. 65).
8. *Marthasterites jucundus* DEFLANDRE (p. 66).
9-11. *Microrhabdulus belgicus* HAY & TOWE (p. 66).
12. *Lithraphidites carniolensis* DEFLANDRE (p. 66).

PLATE 40

FIGURE

1-2. *Lithraphidites carniolensis* DEFLANDRE (p. 66).
3. *Lithraphidites grossopectinatus* BUKRY, n. sp. (p. 66).
4. *Lucianorhabdus cayeuxi* DEFLANDRE (p. 66).
5-6. *Micula decussata decussata* VEKSHINA (p. 67).
7-8. *Micula decussata concava* (Stradner), BUKRY, n. comb. (p. 67).
9-12. *Nannoconus farinaccae* BUKRY, n. sp. (p. 67).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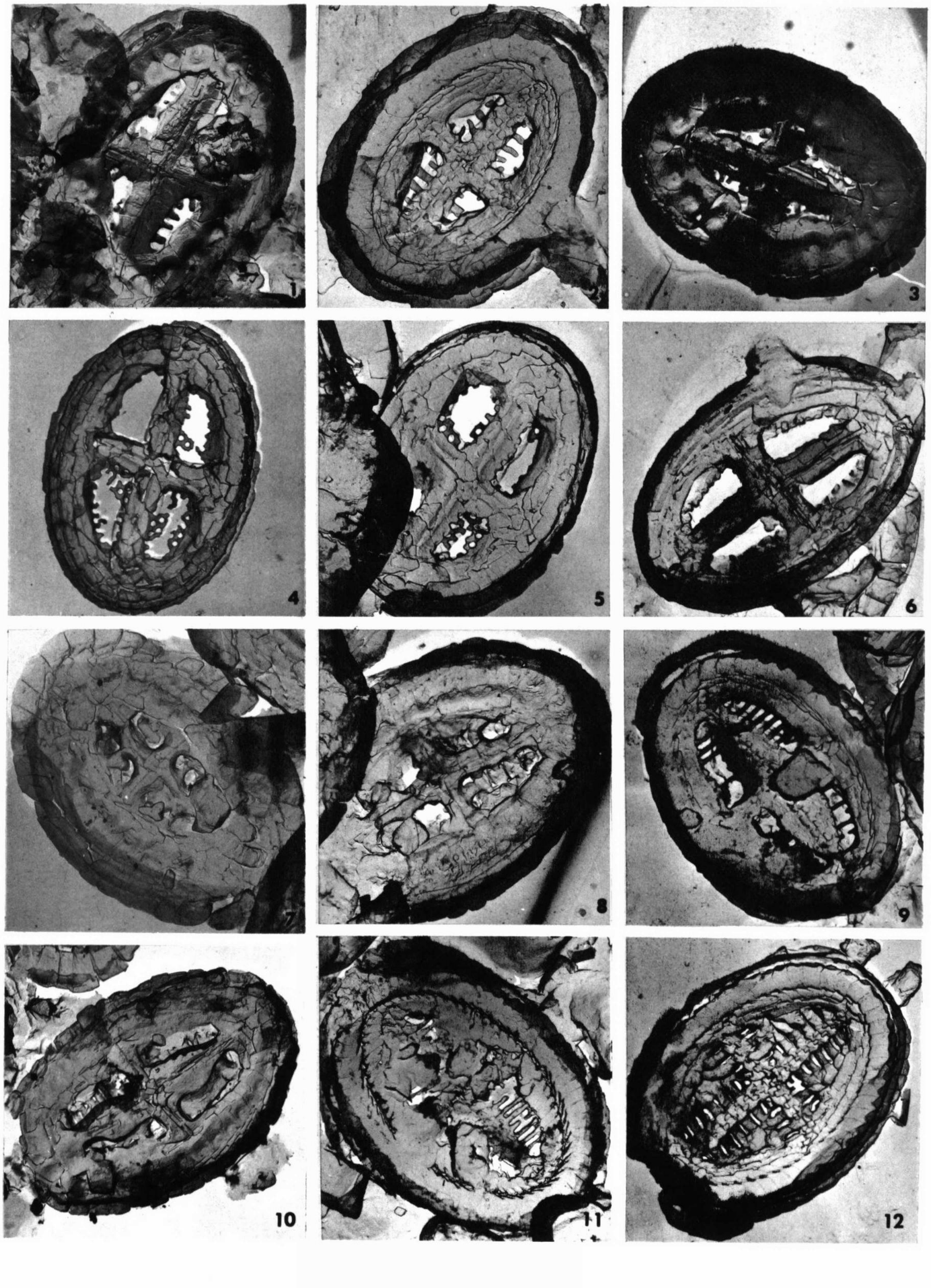
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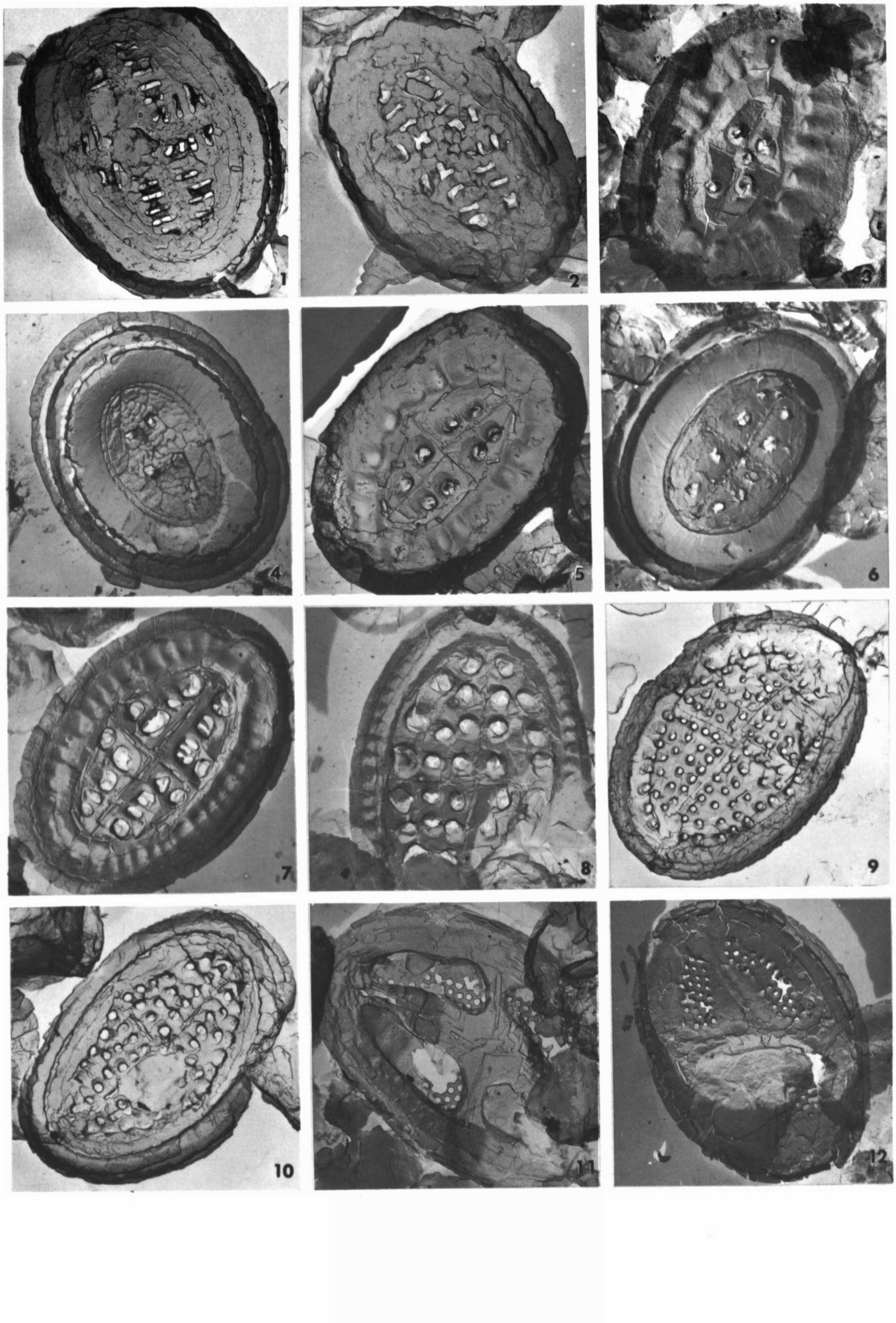
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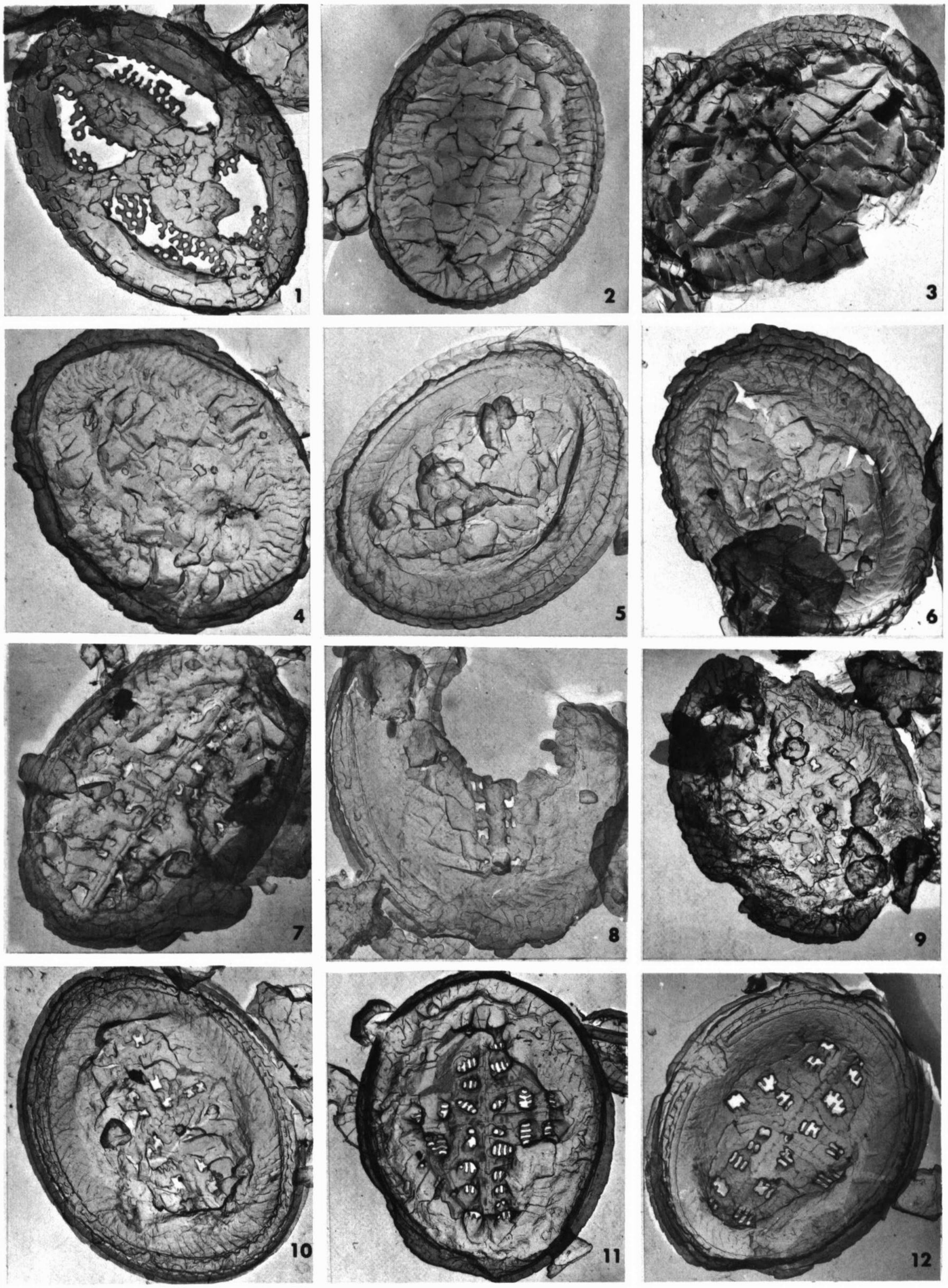
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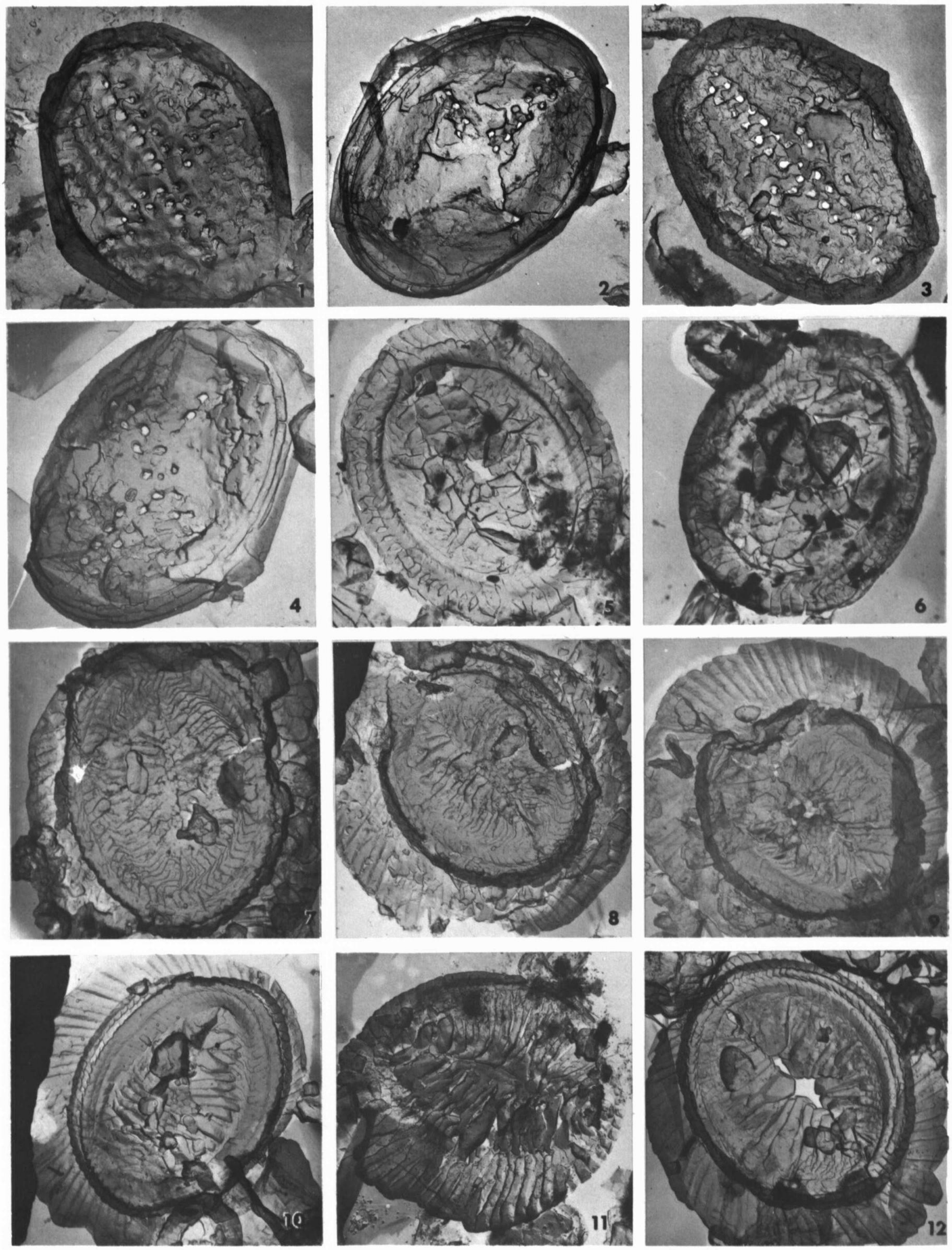
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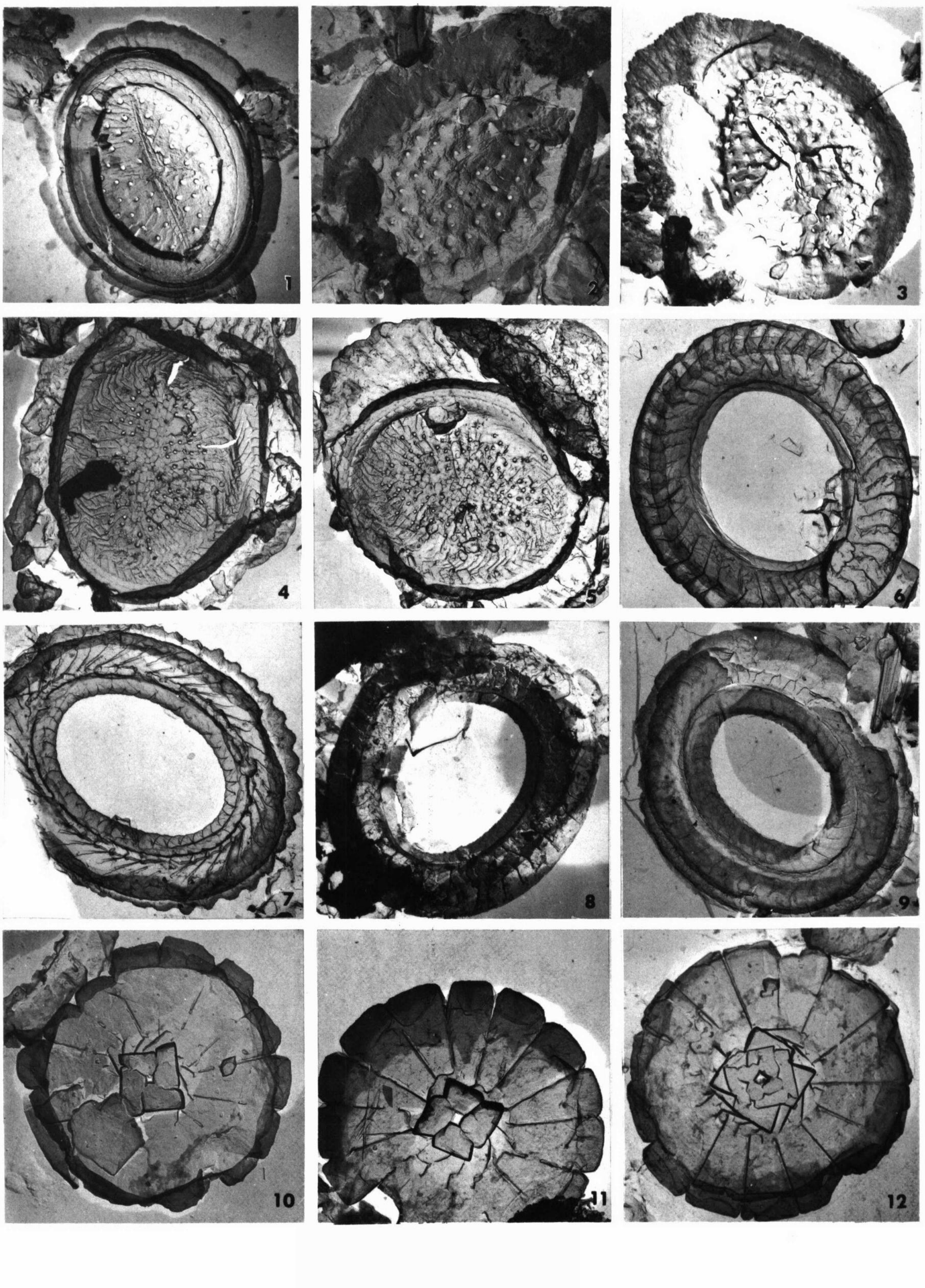
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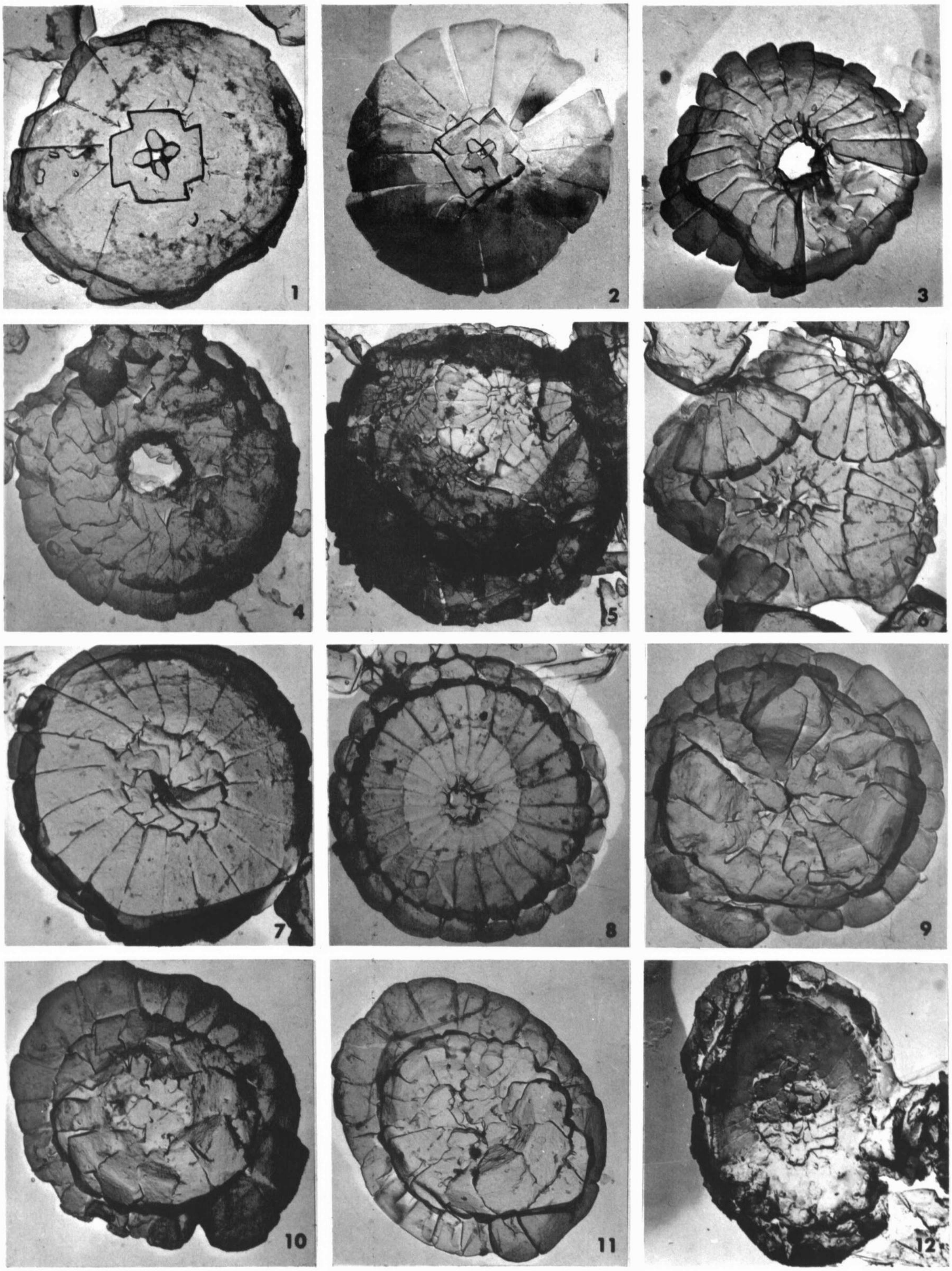
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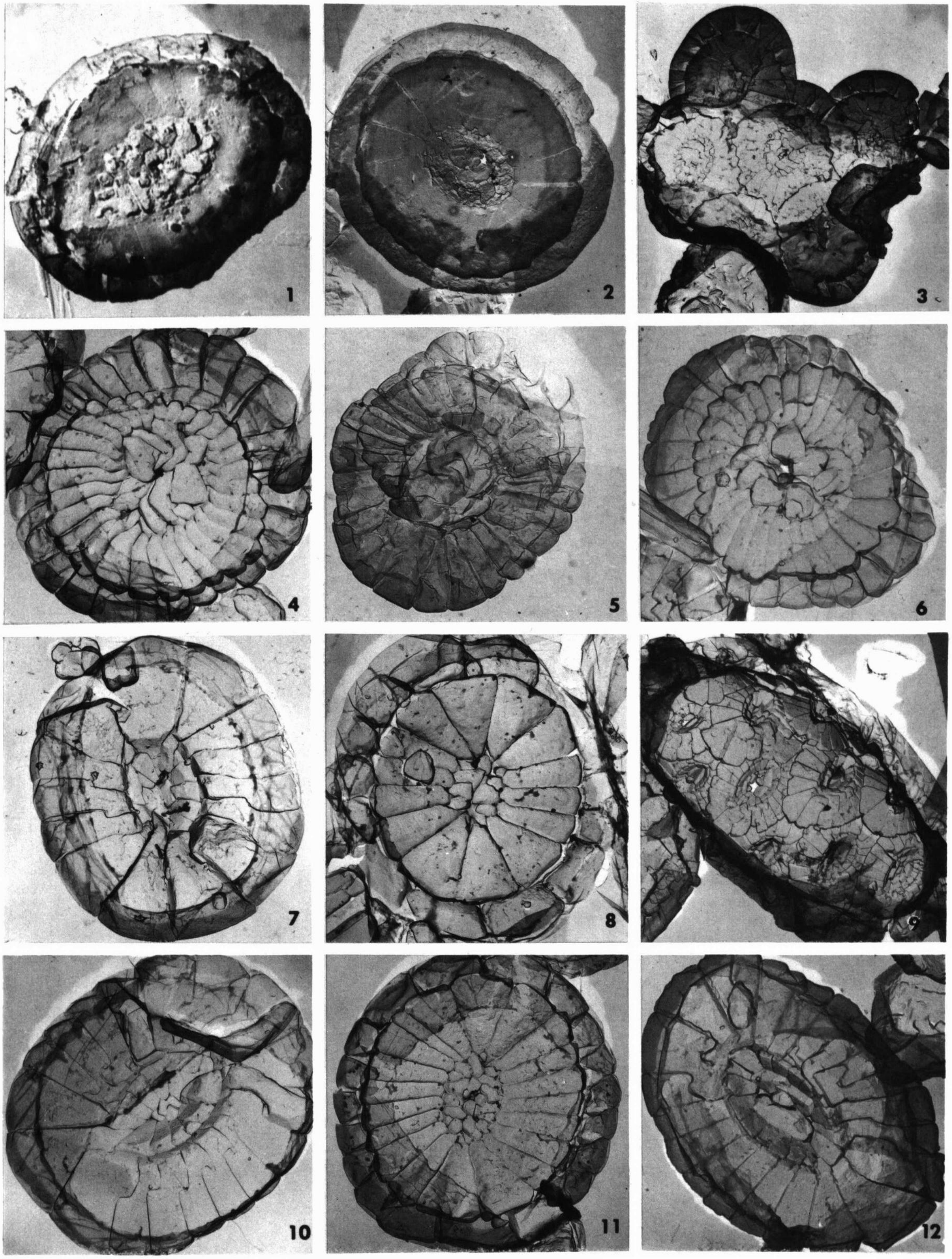
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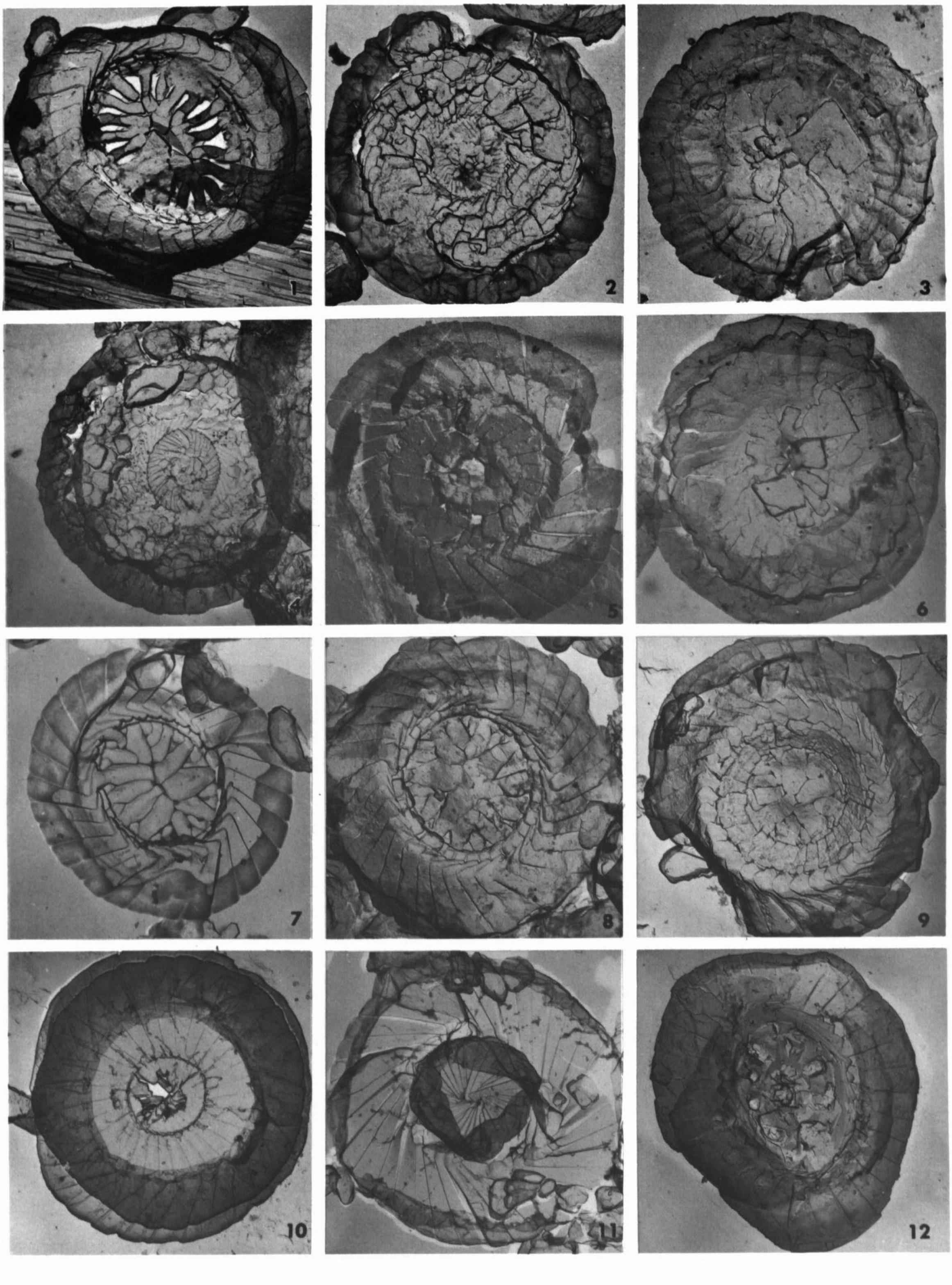
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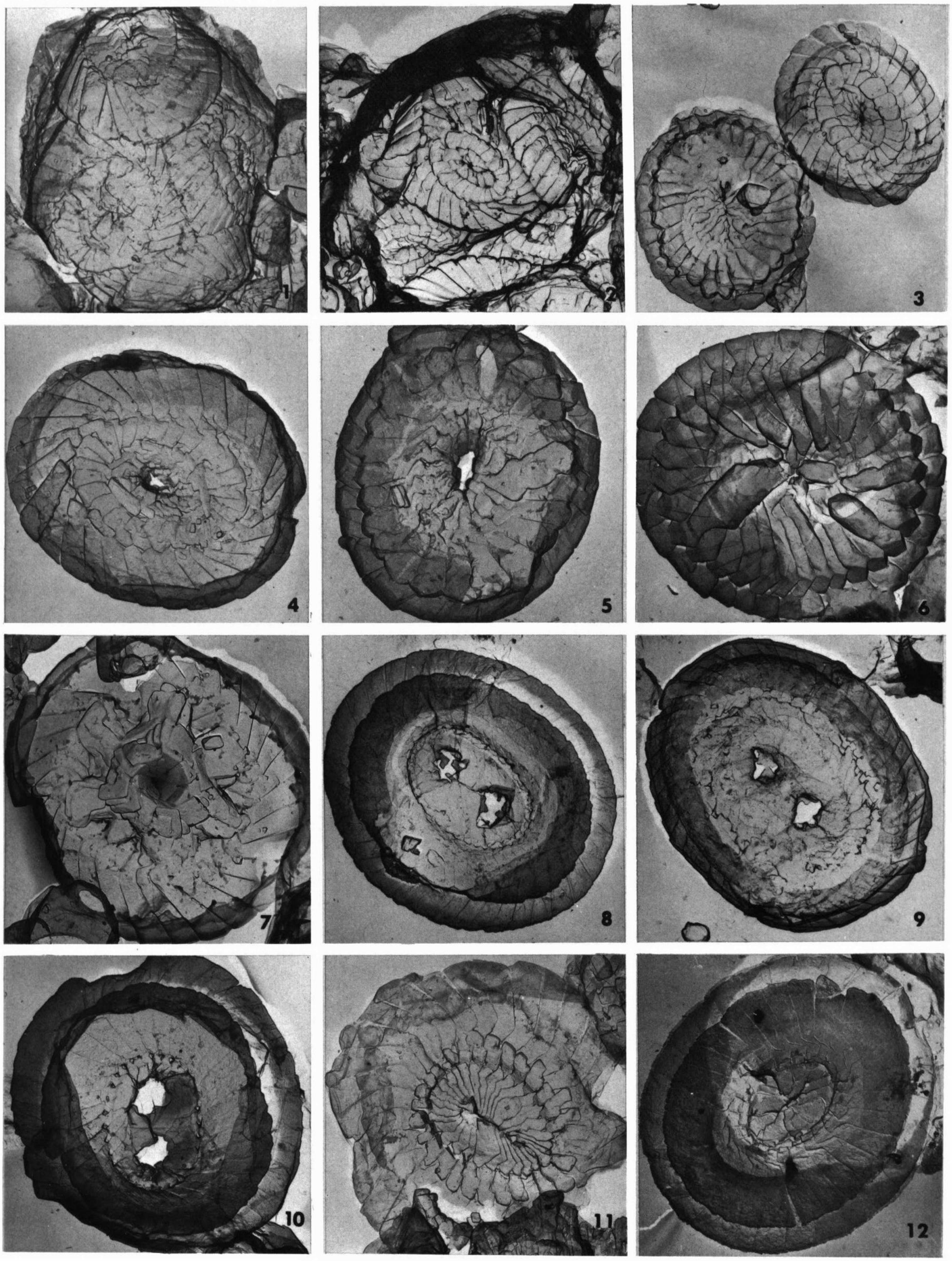

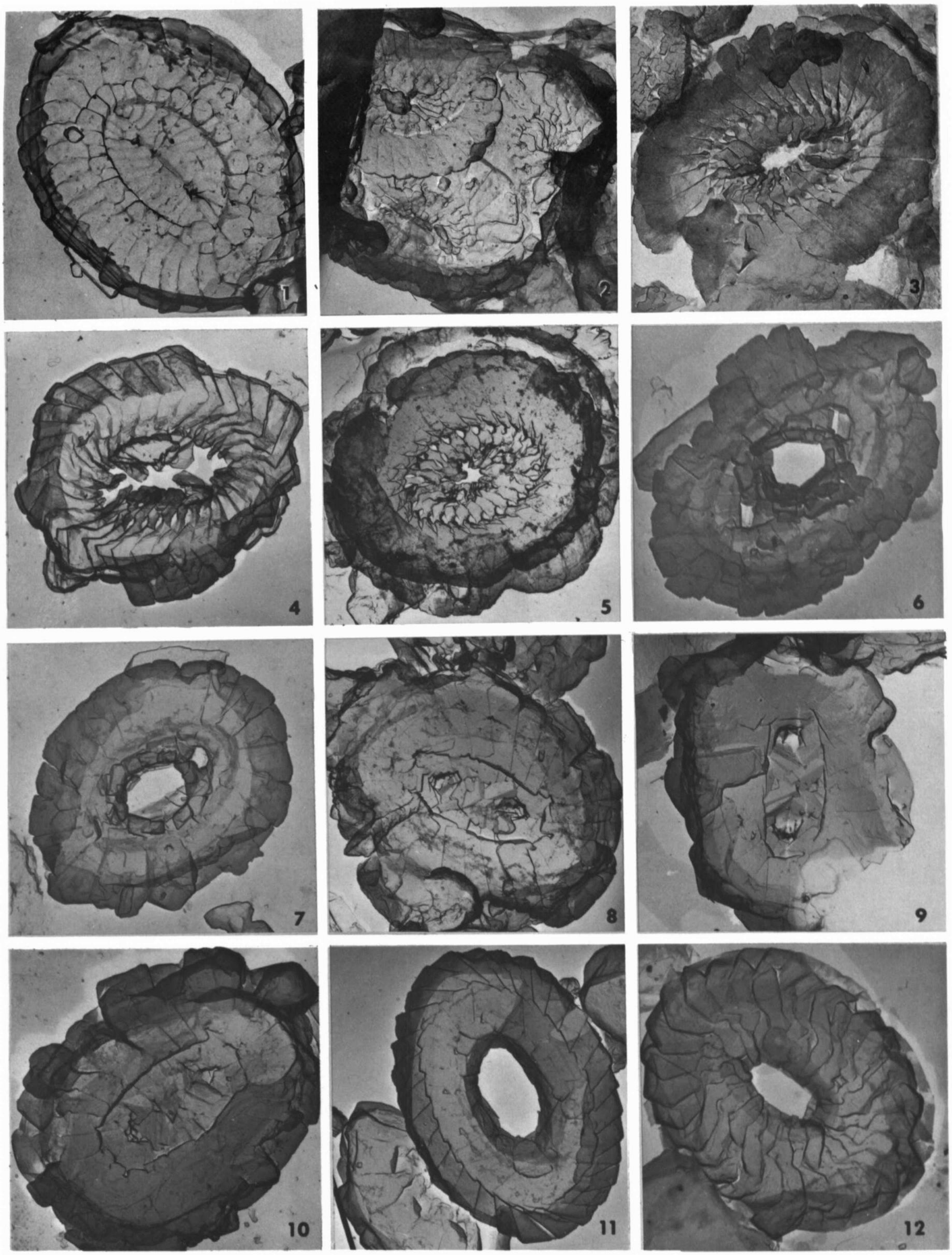
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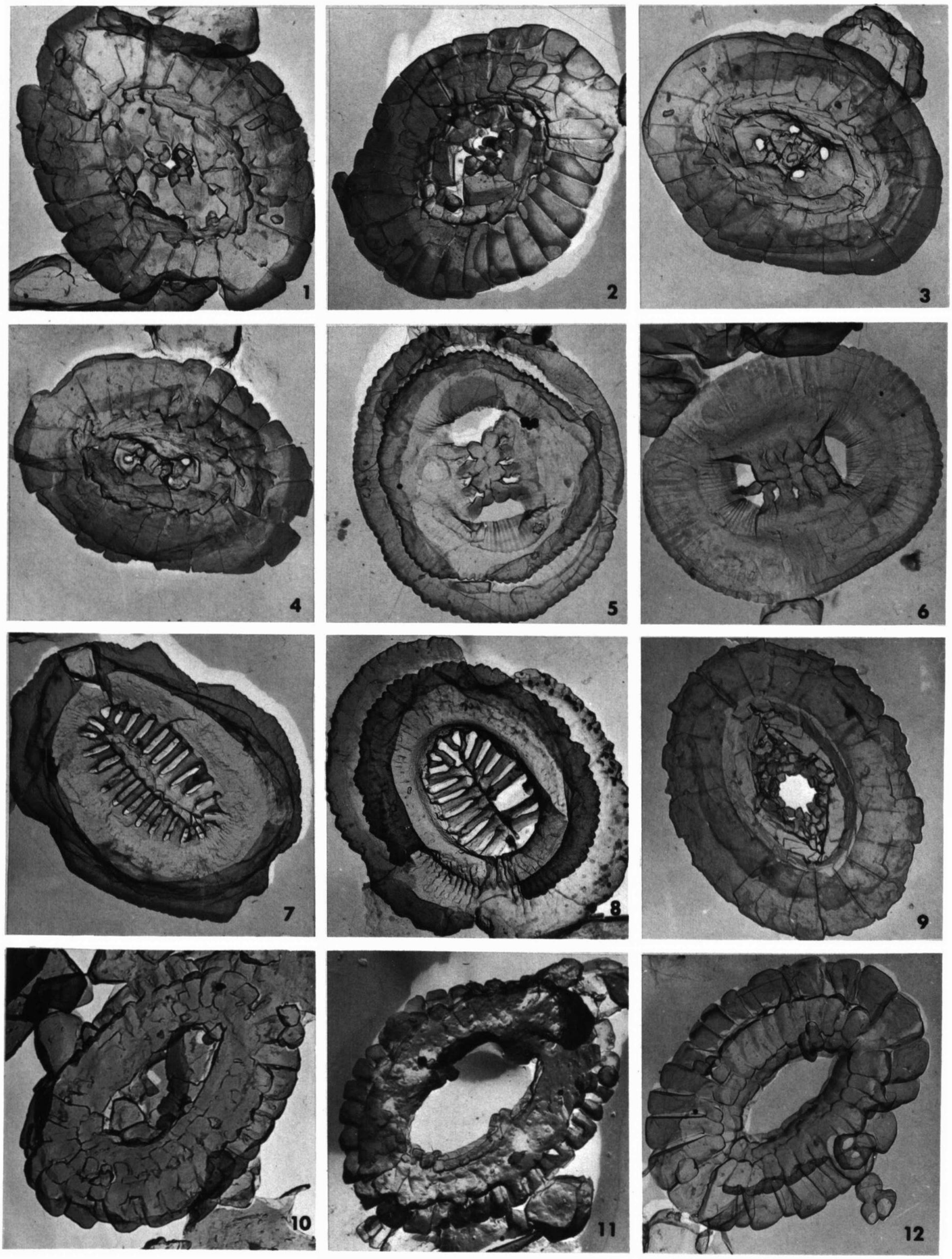
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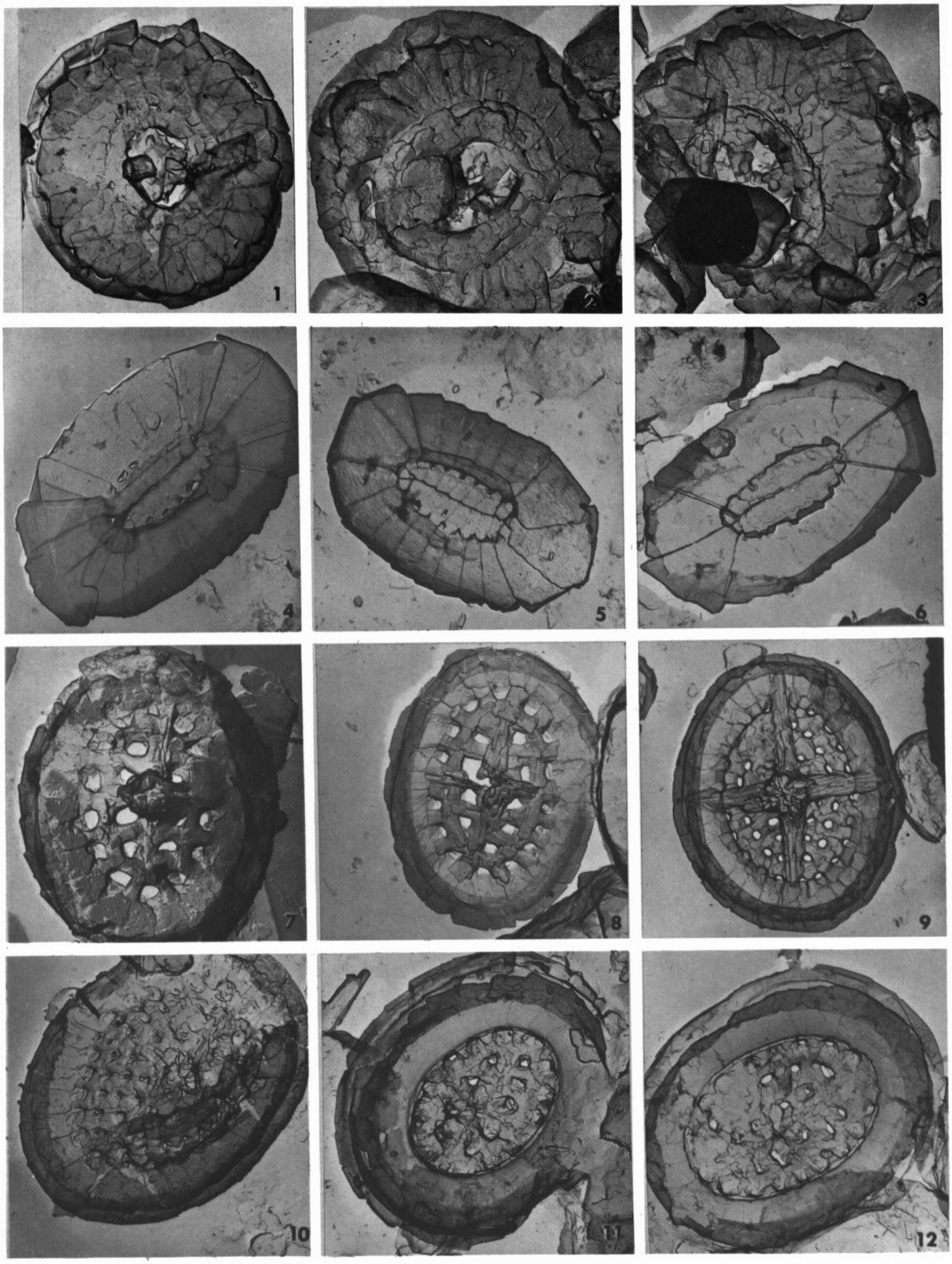
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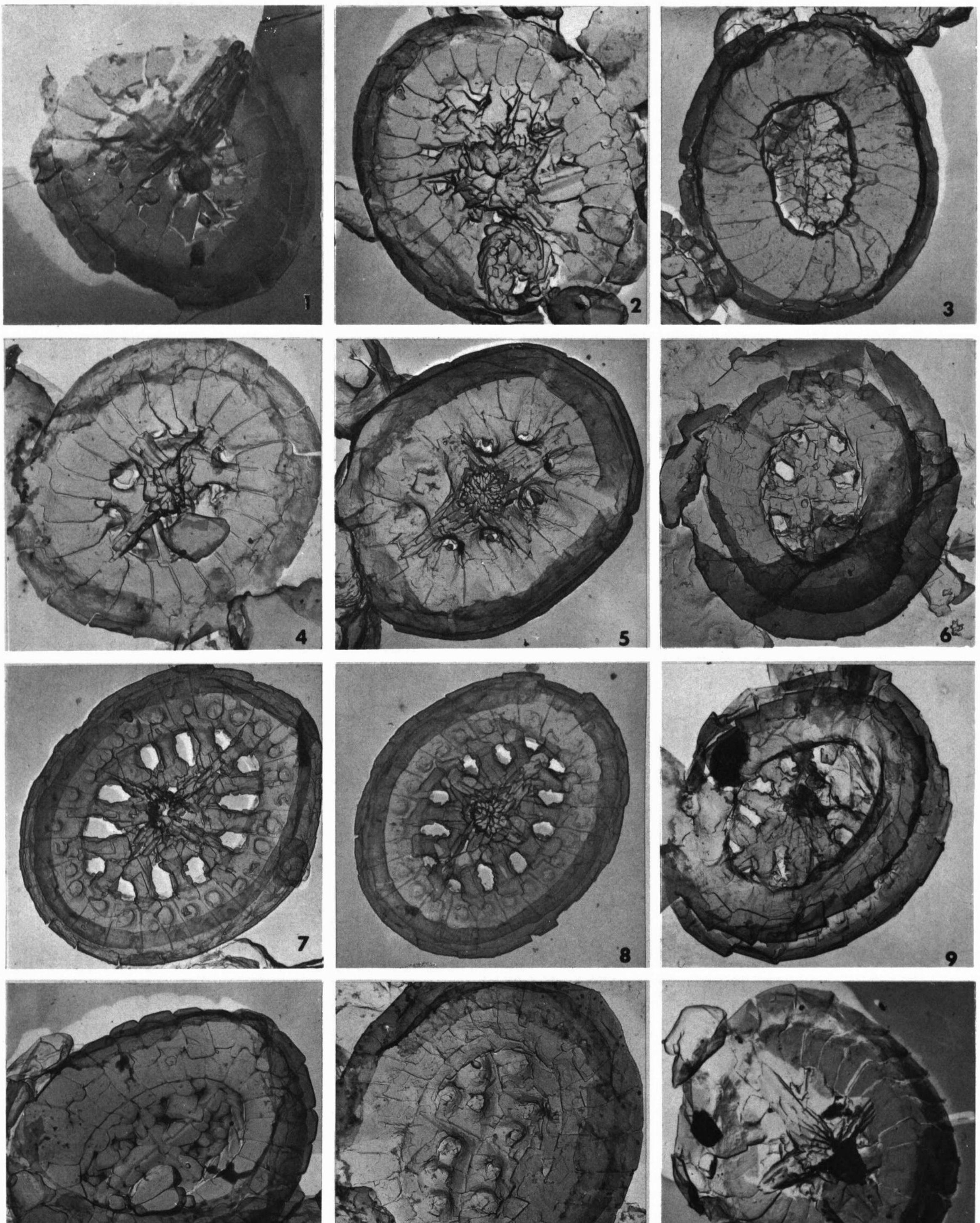
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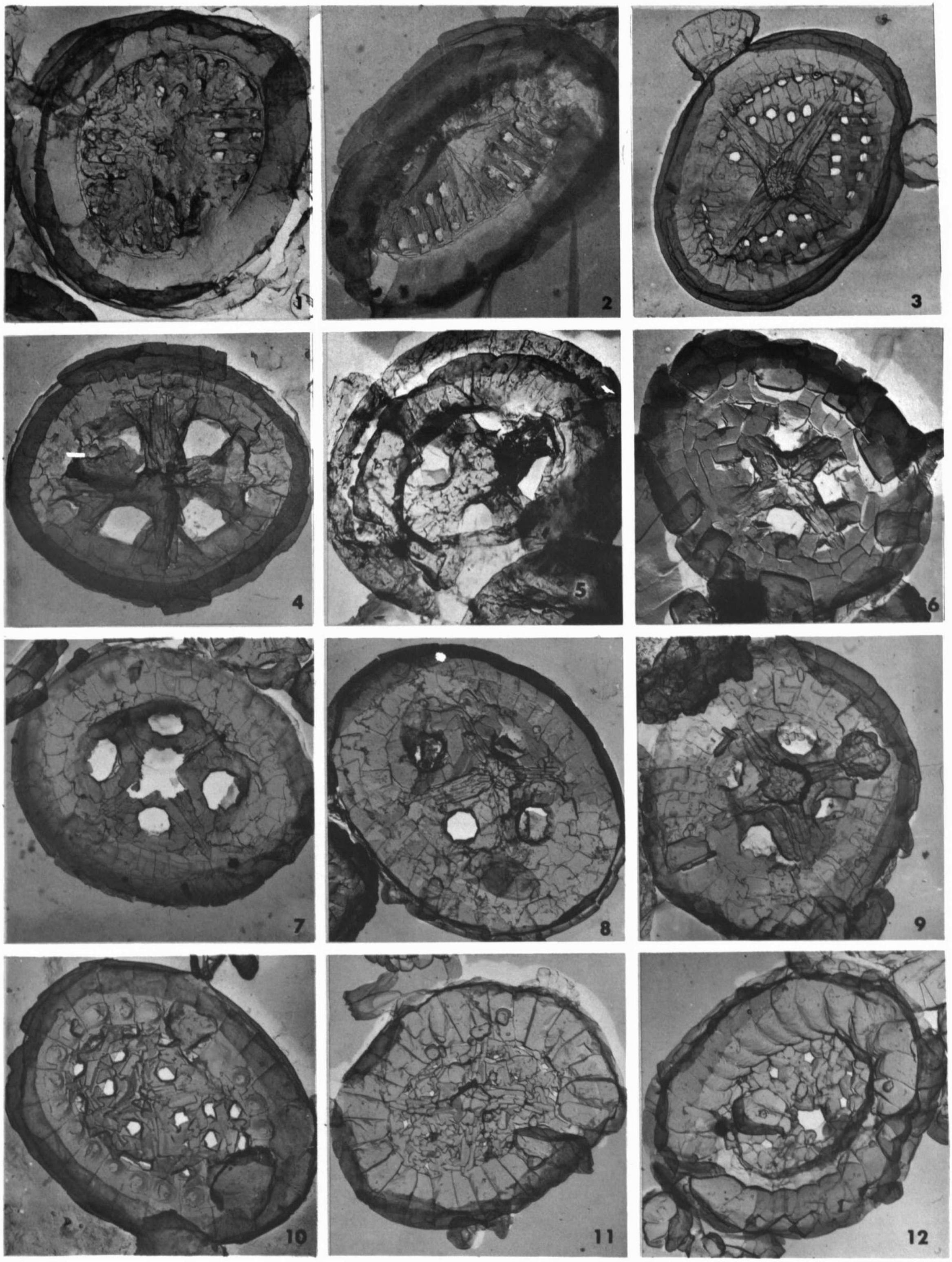
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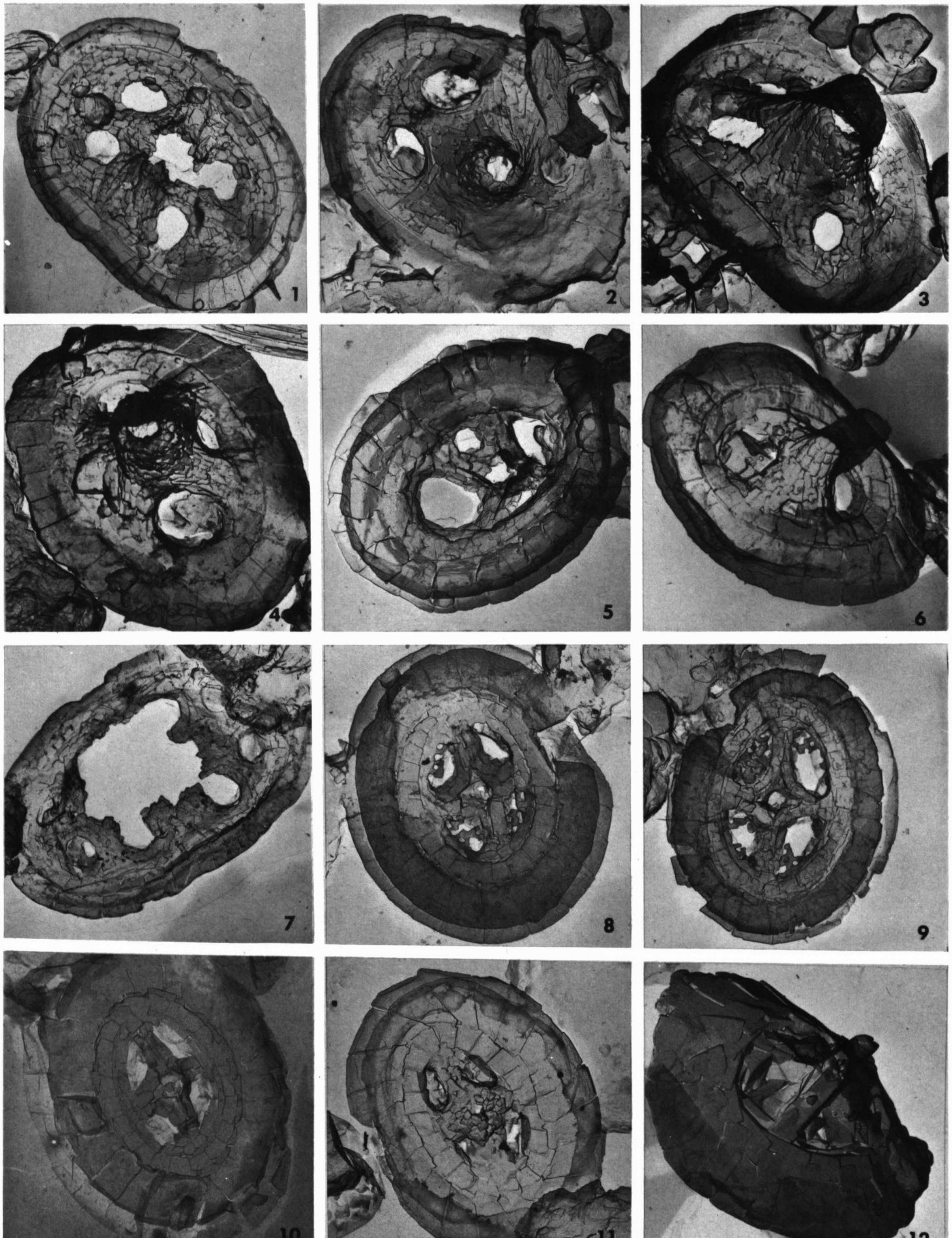
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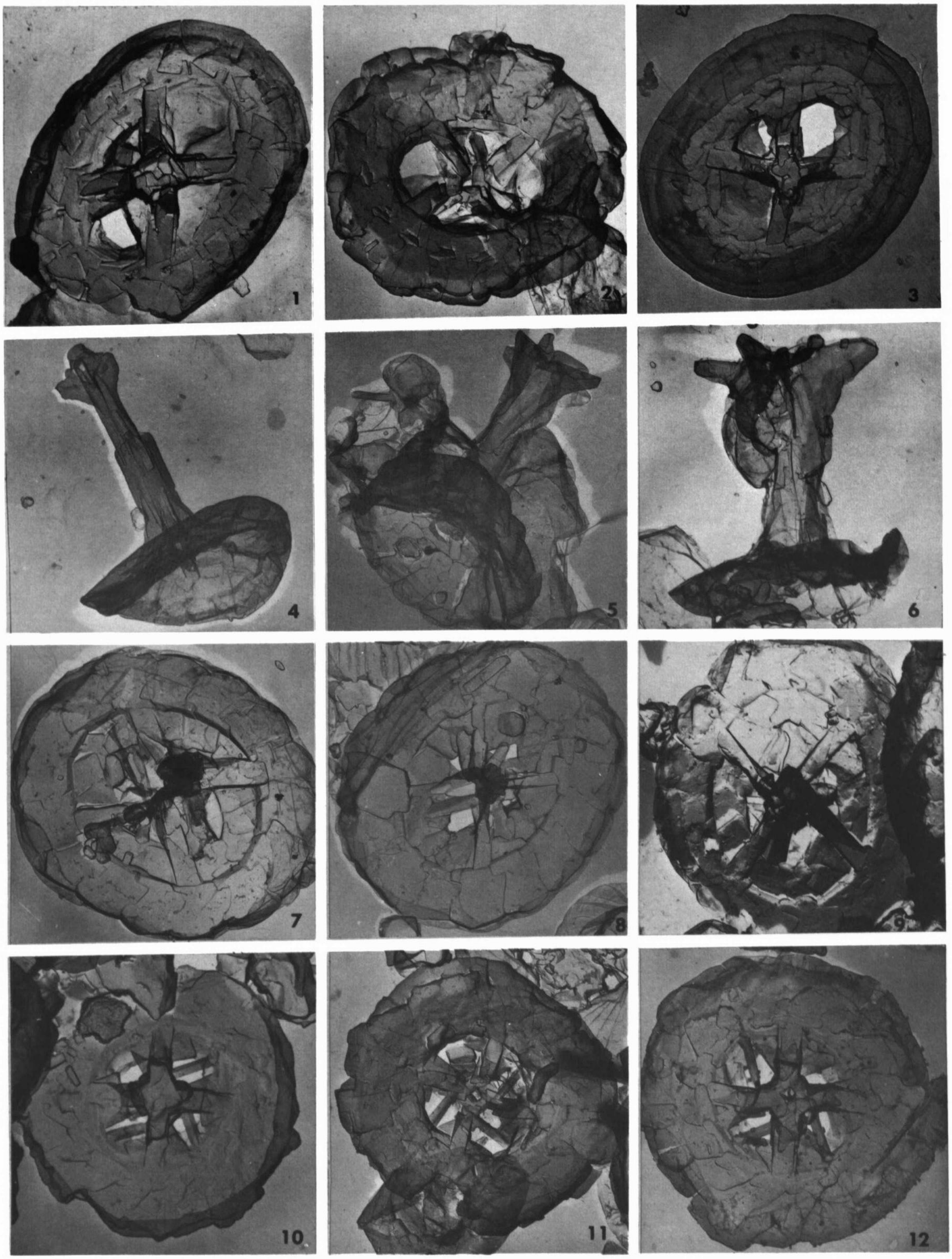
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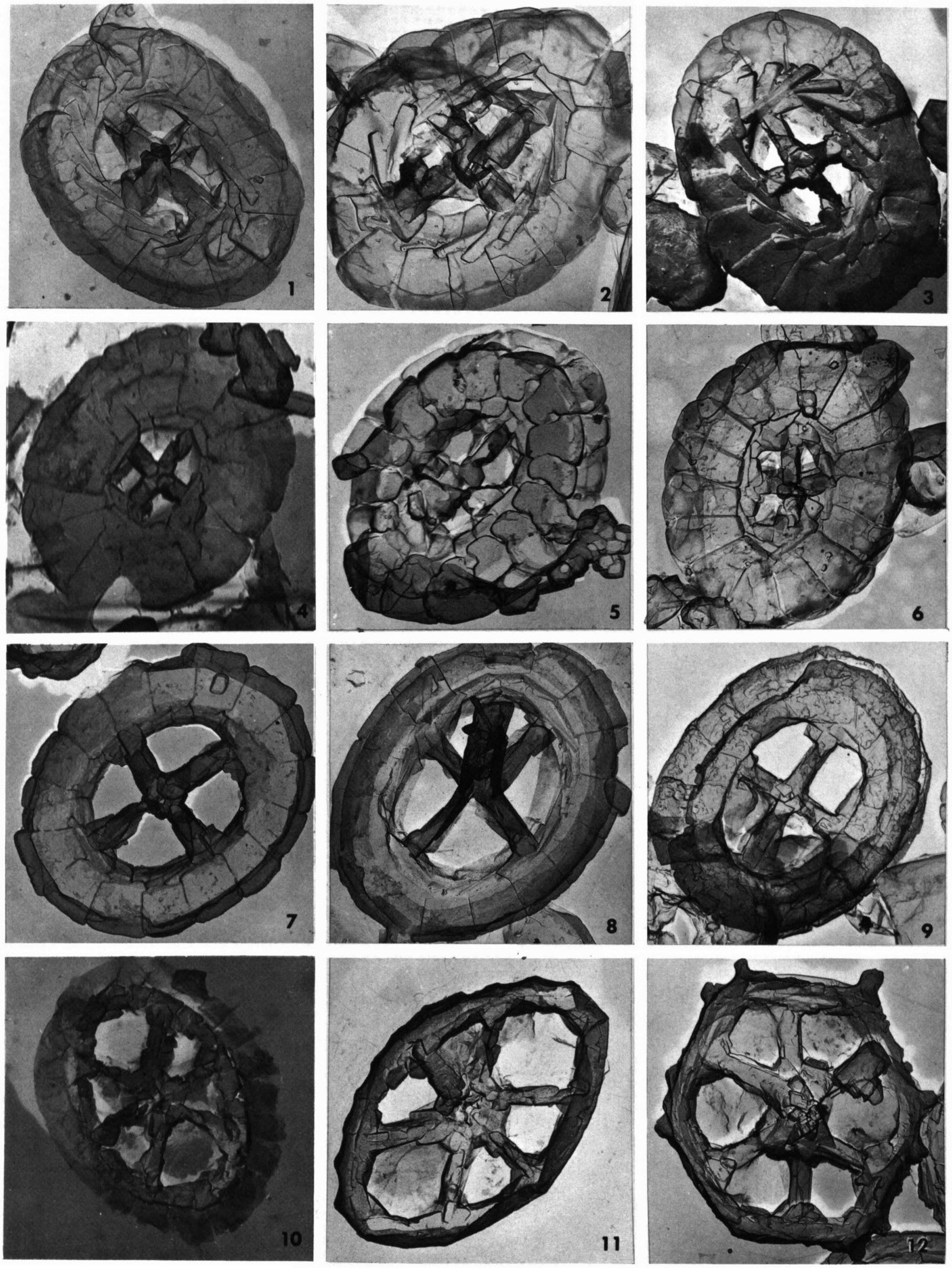
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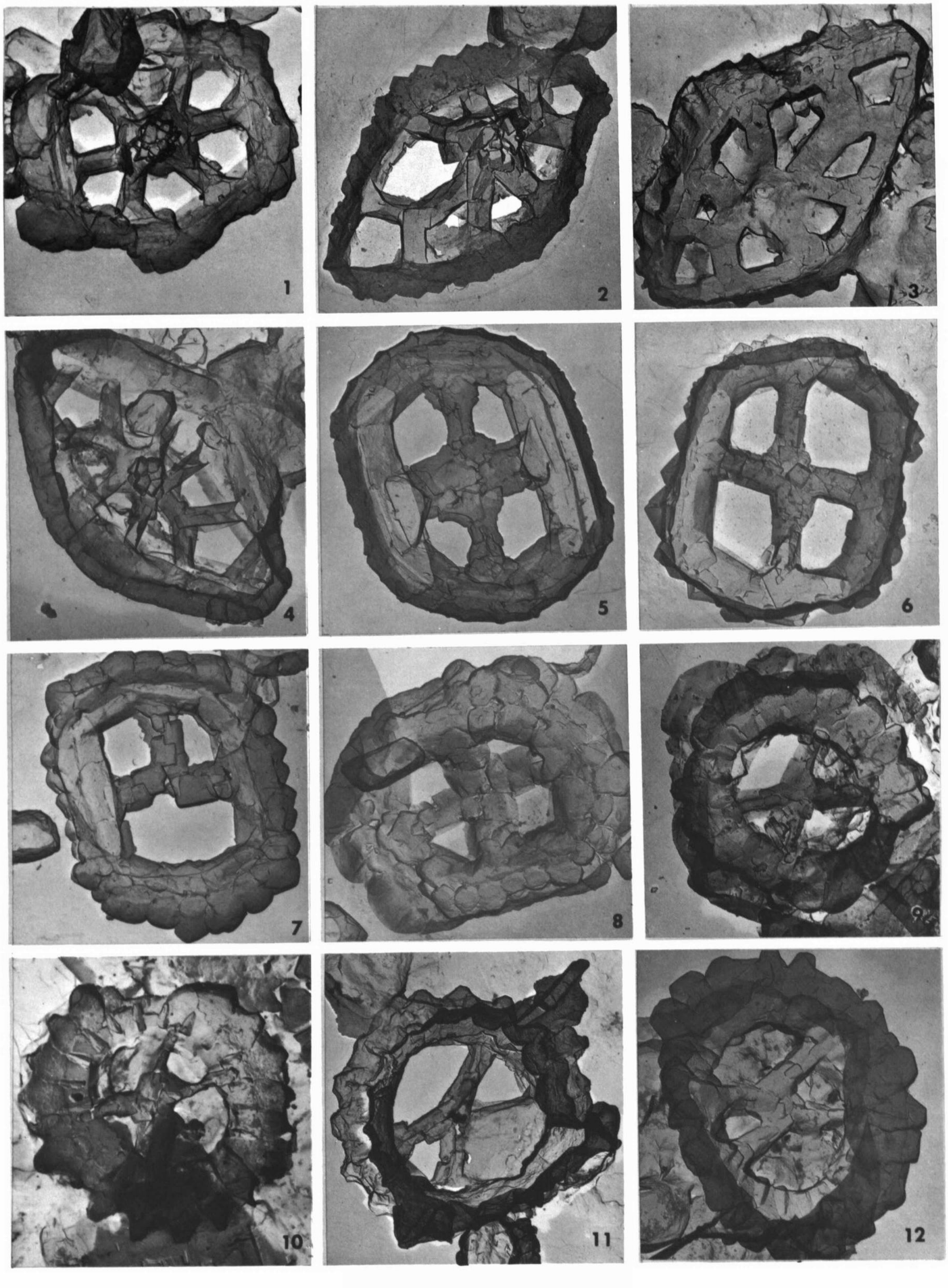
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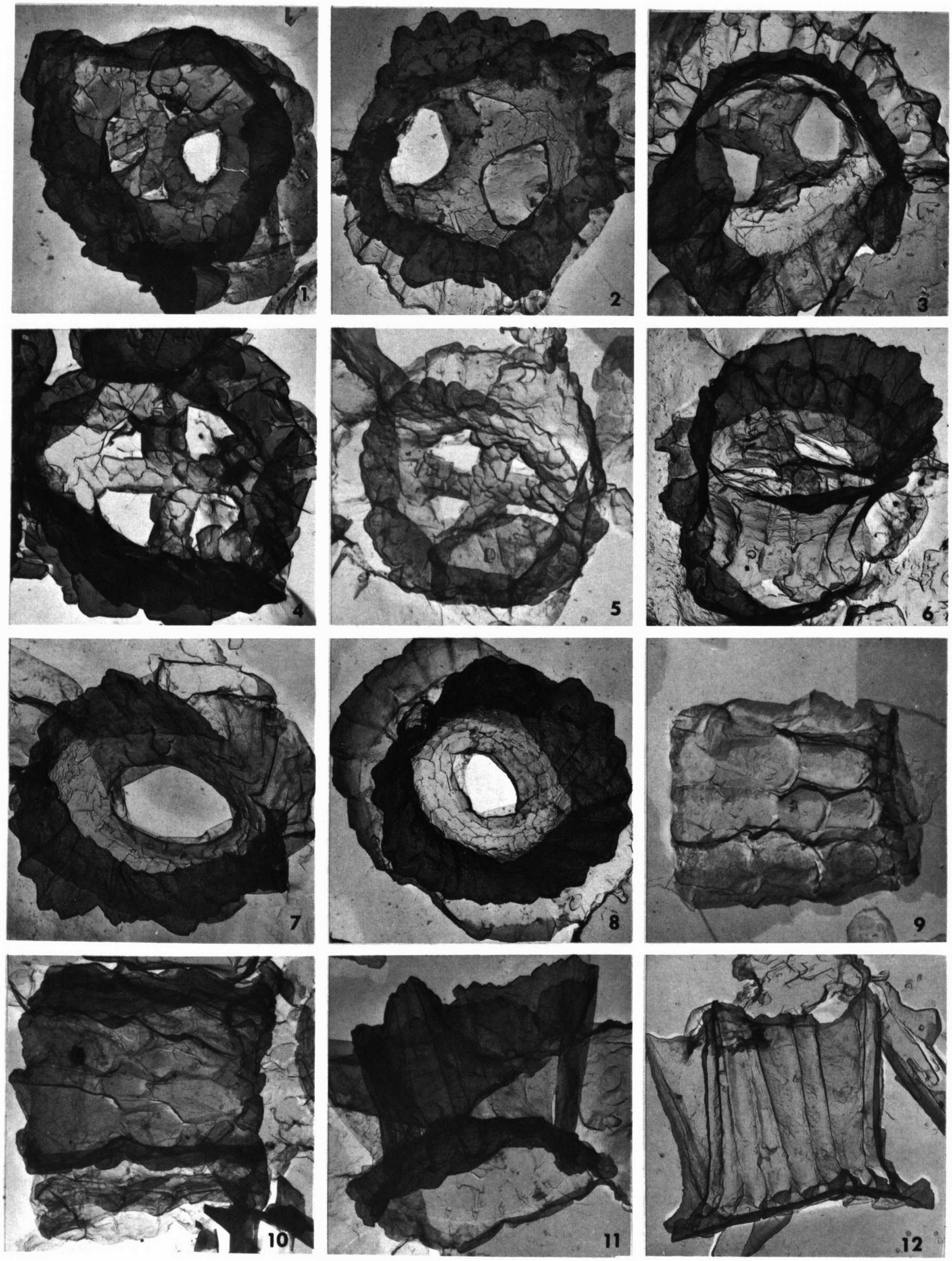
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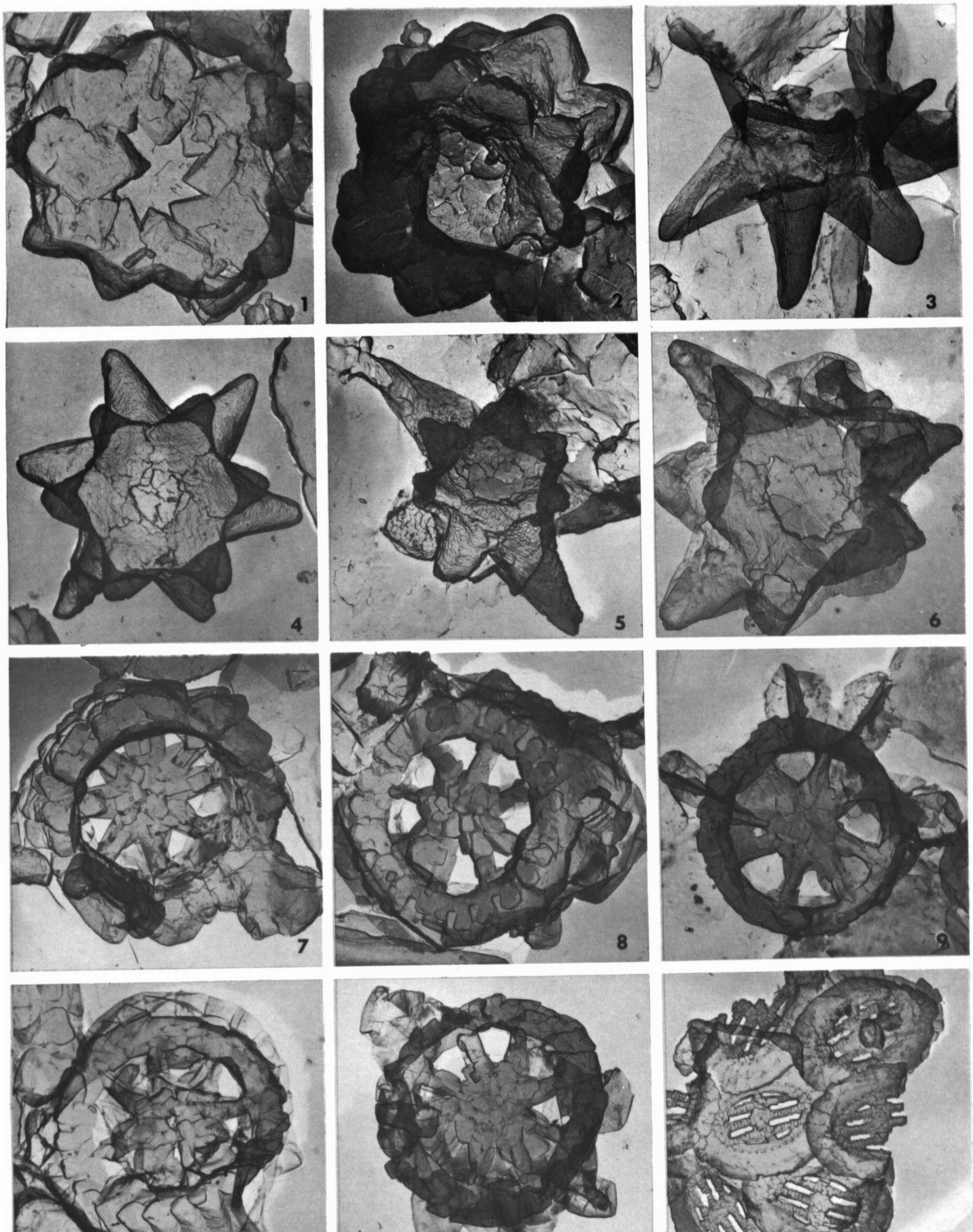
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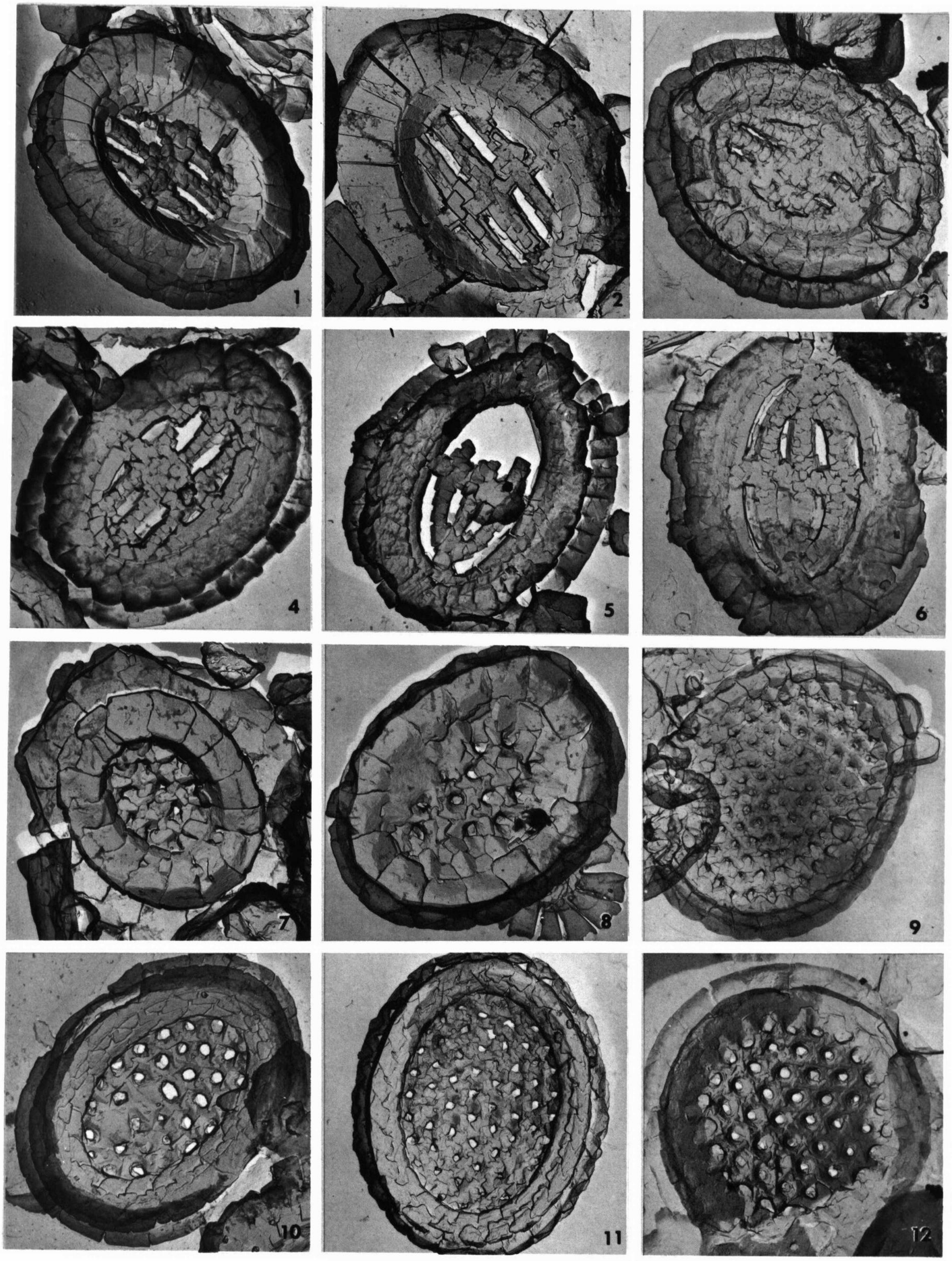
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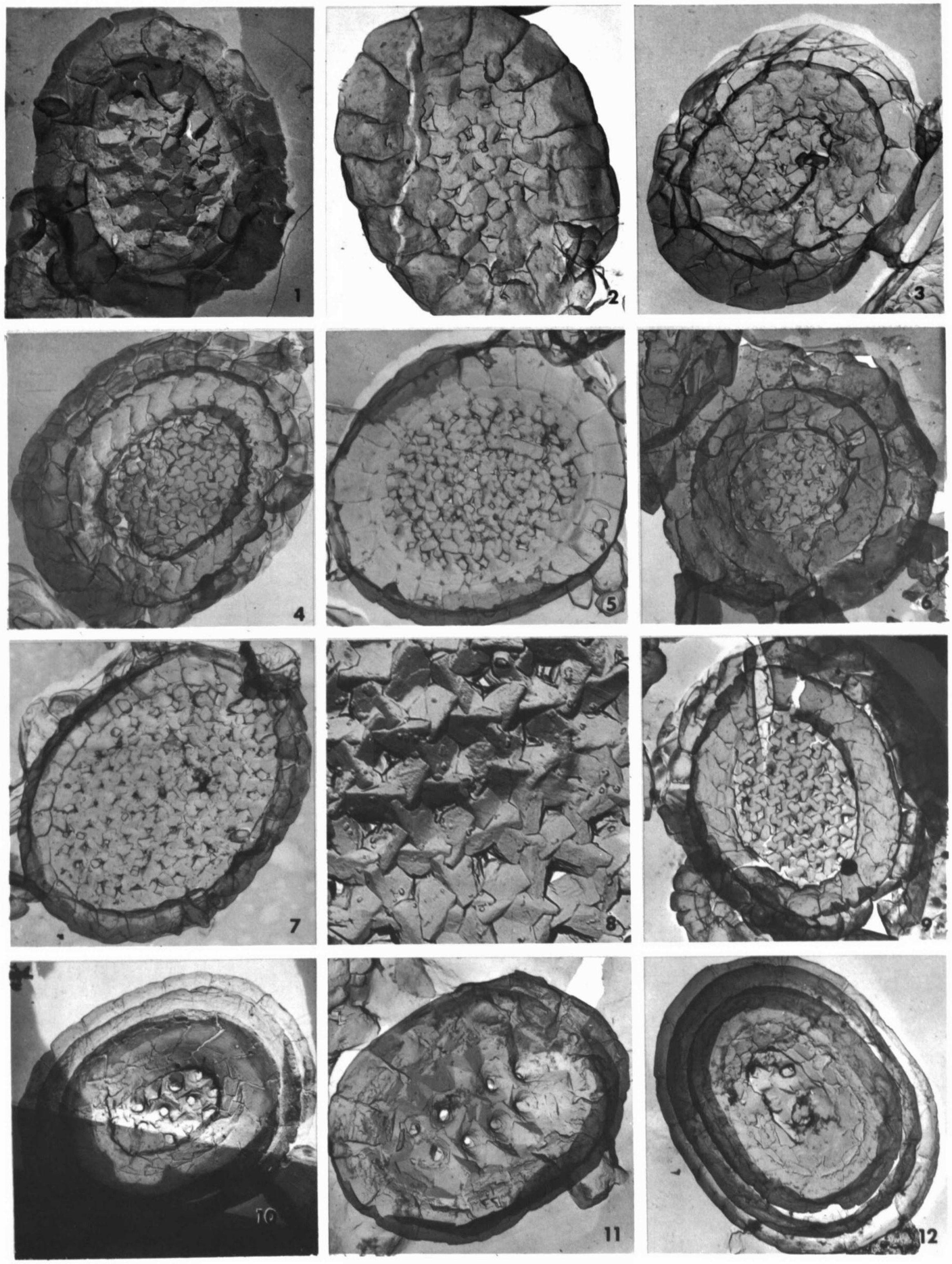
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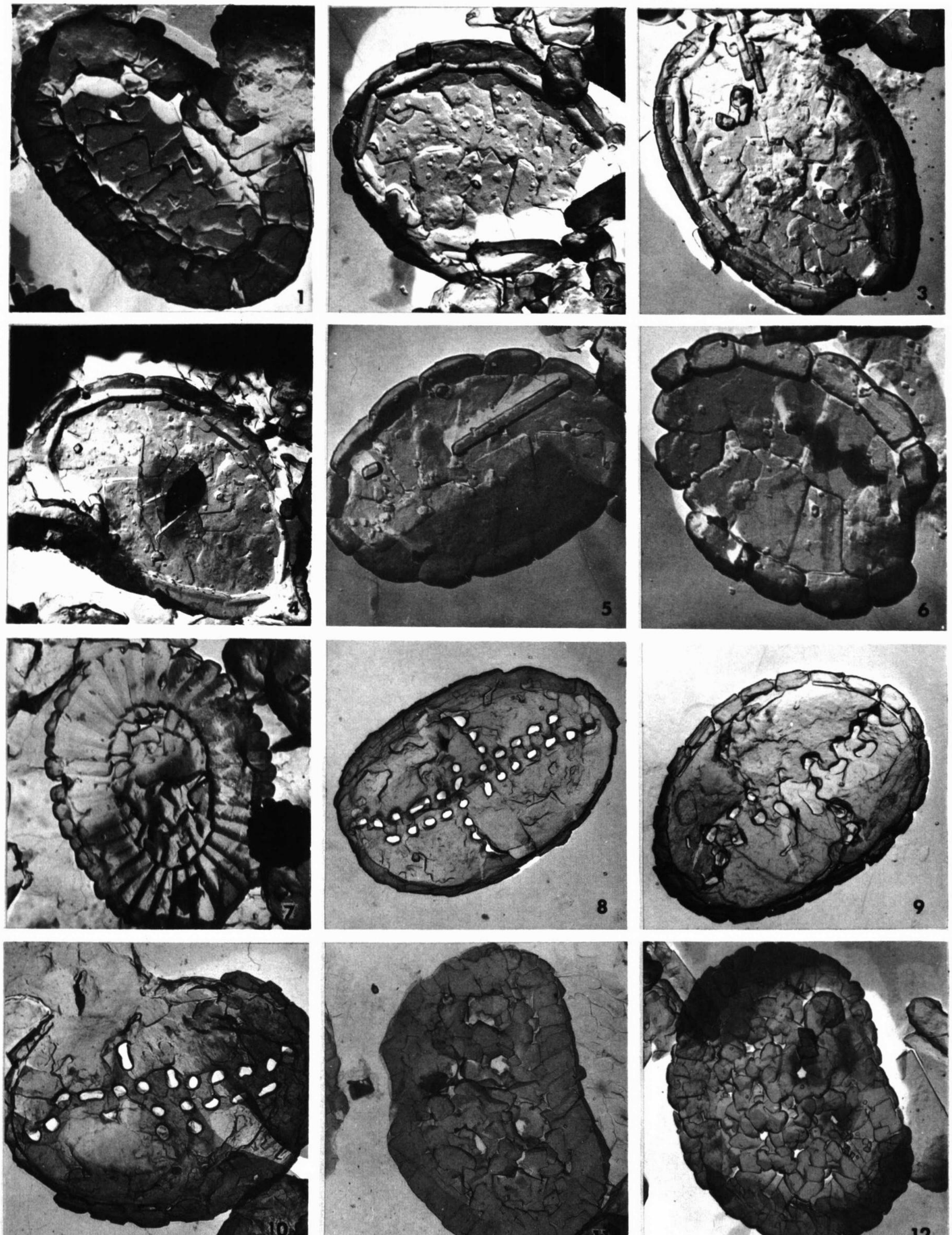
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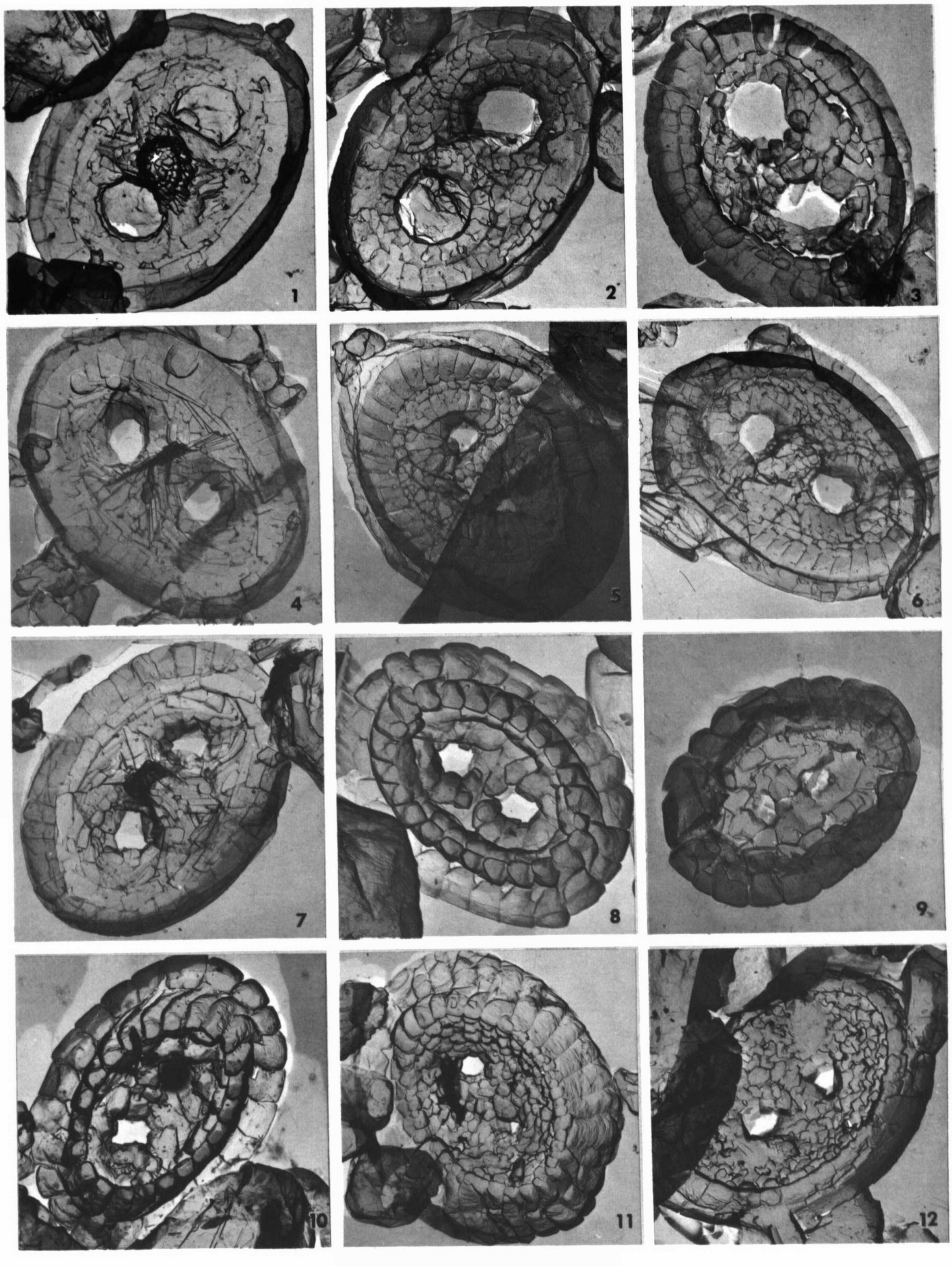

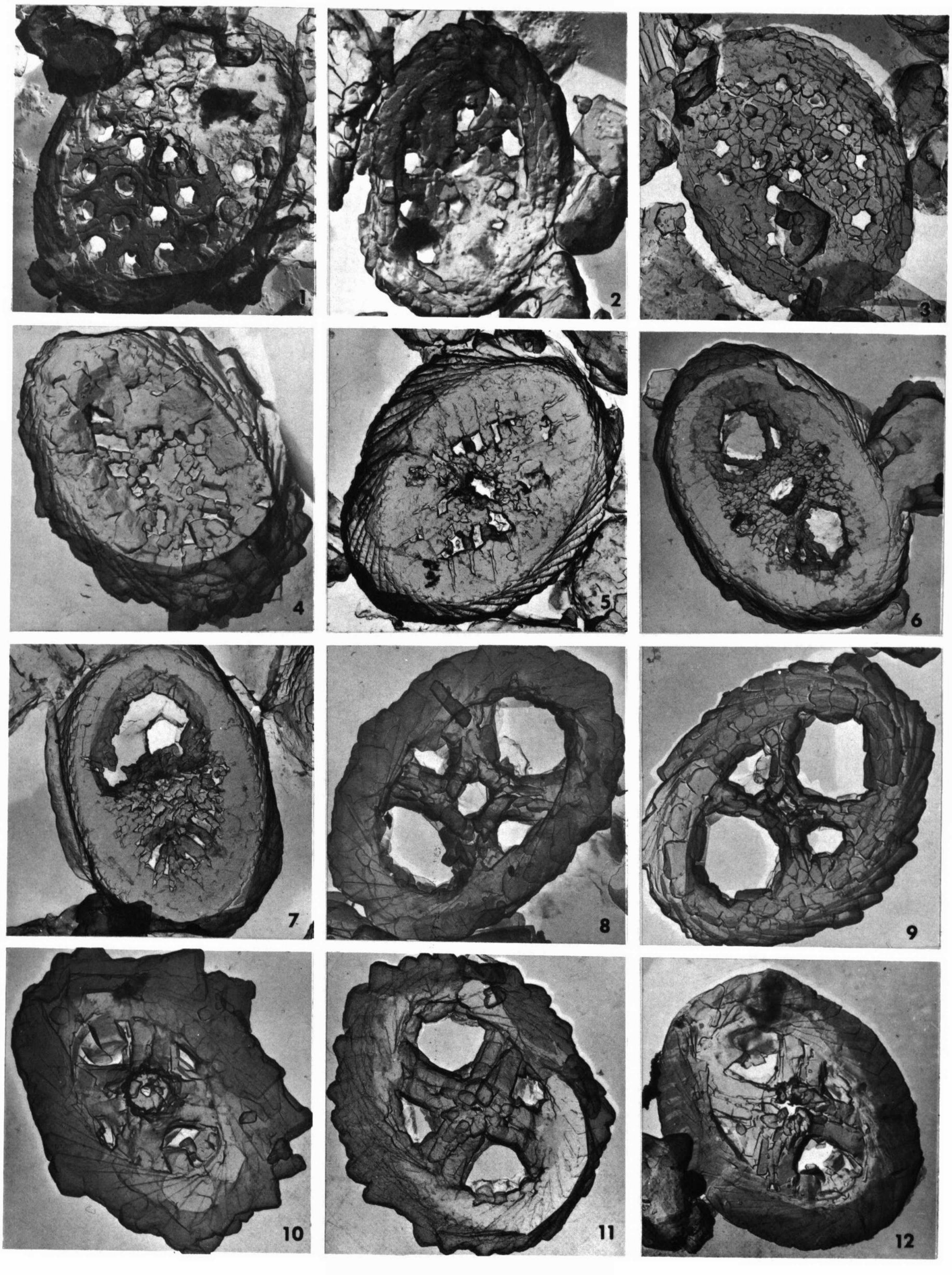
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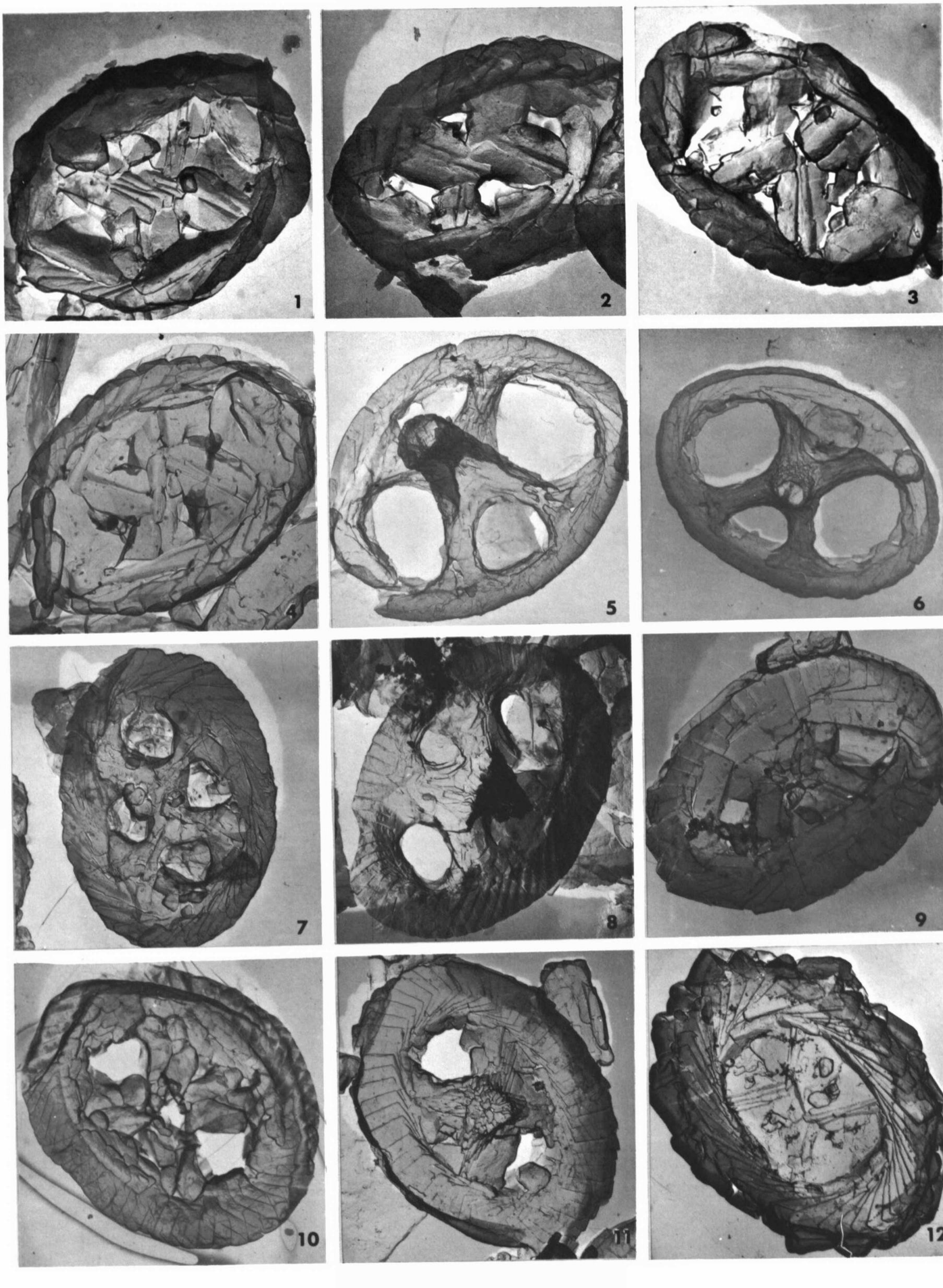
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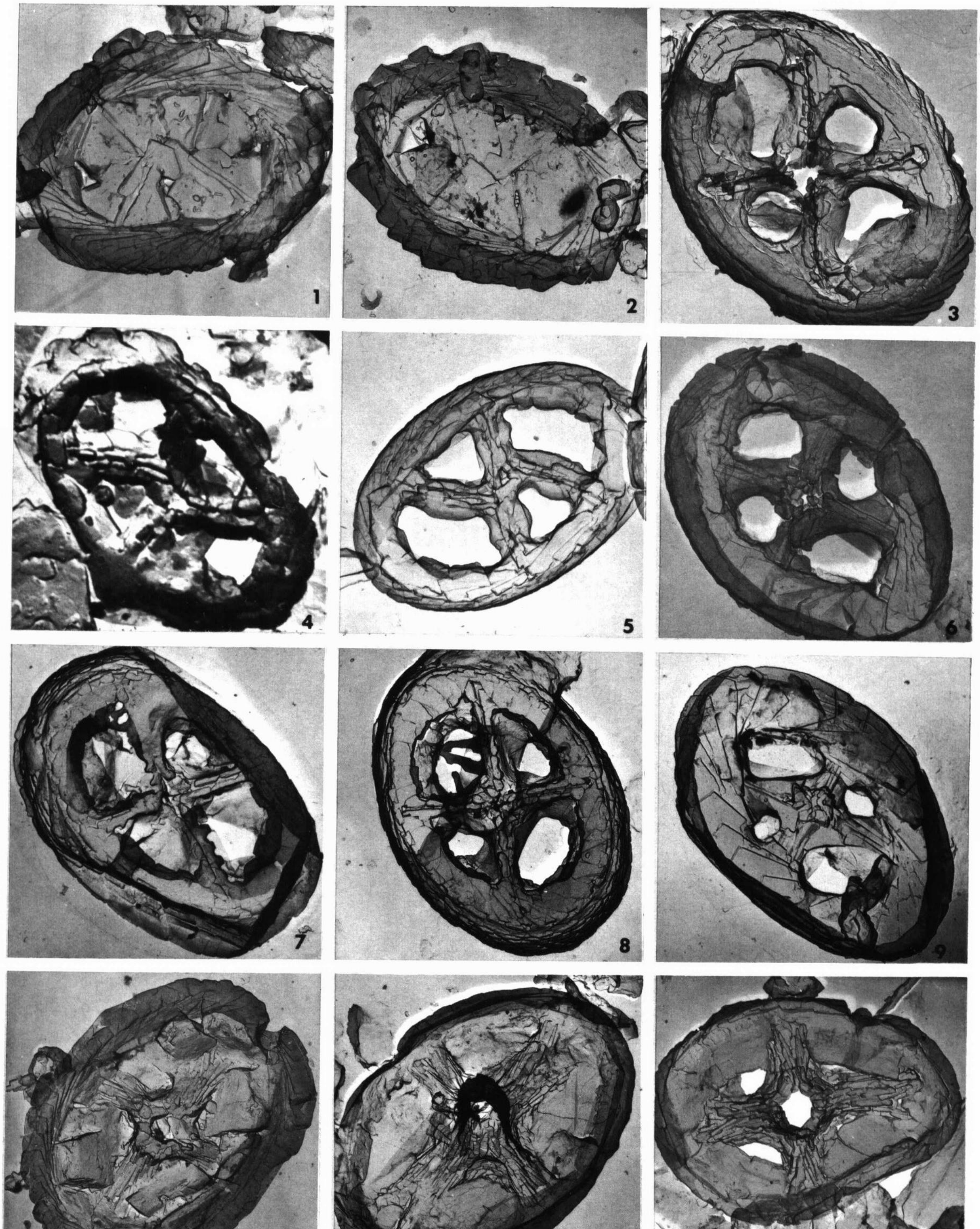
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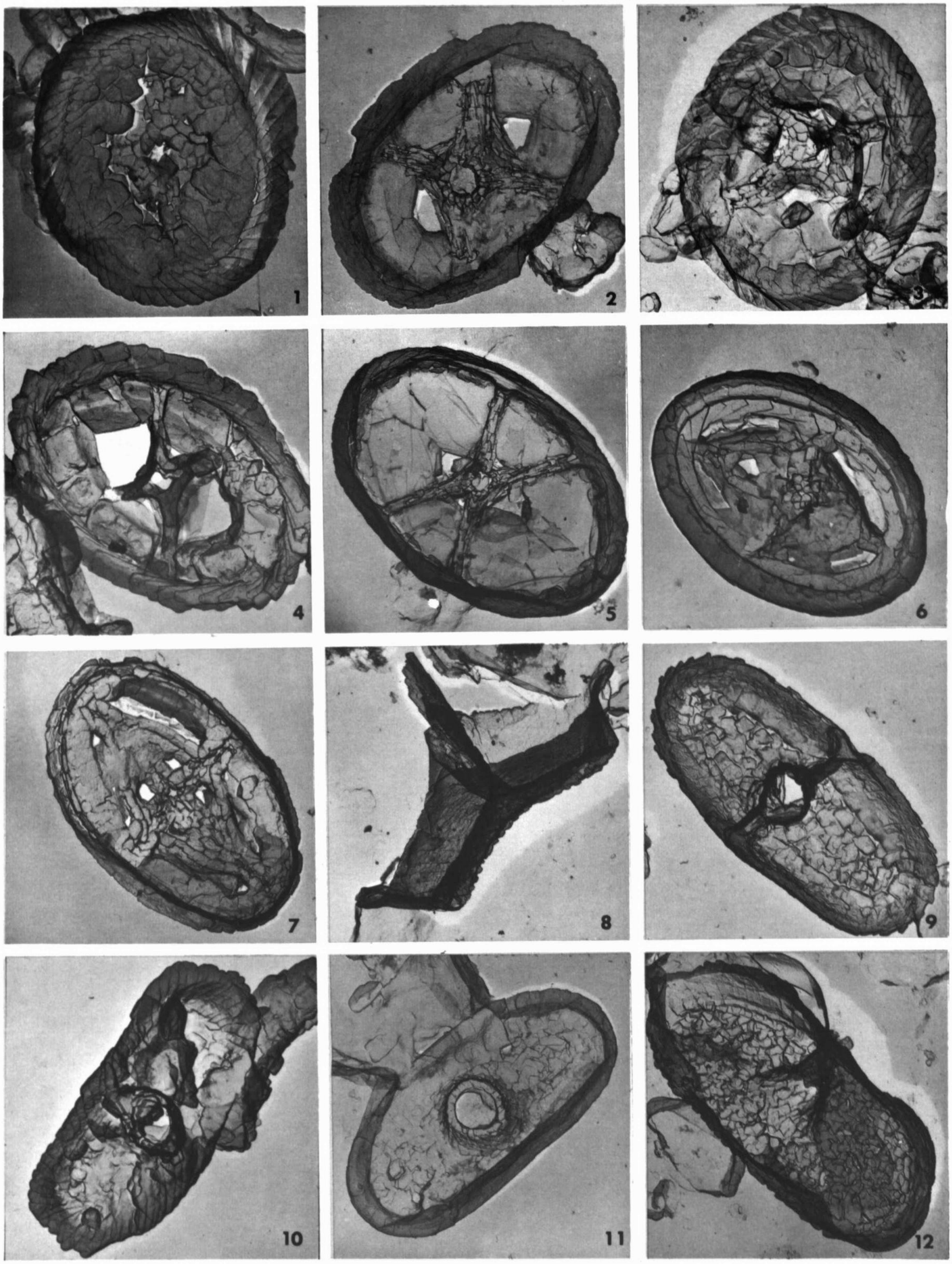
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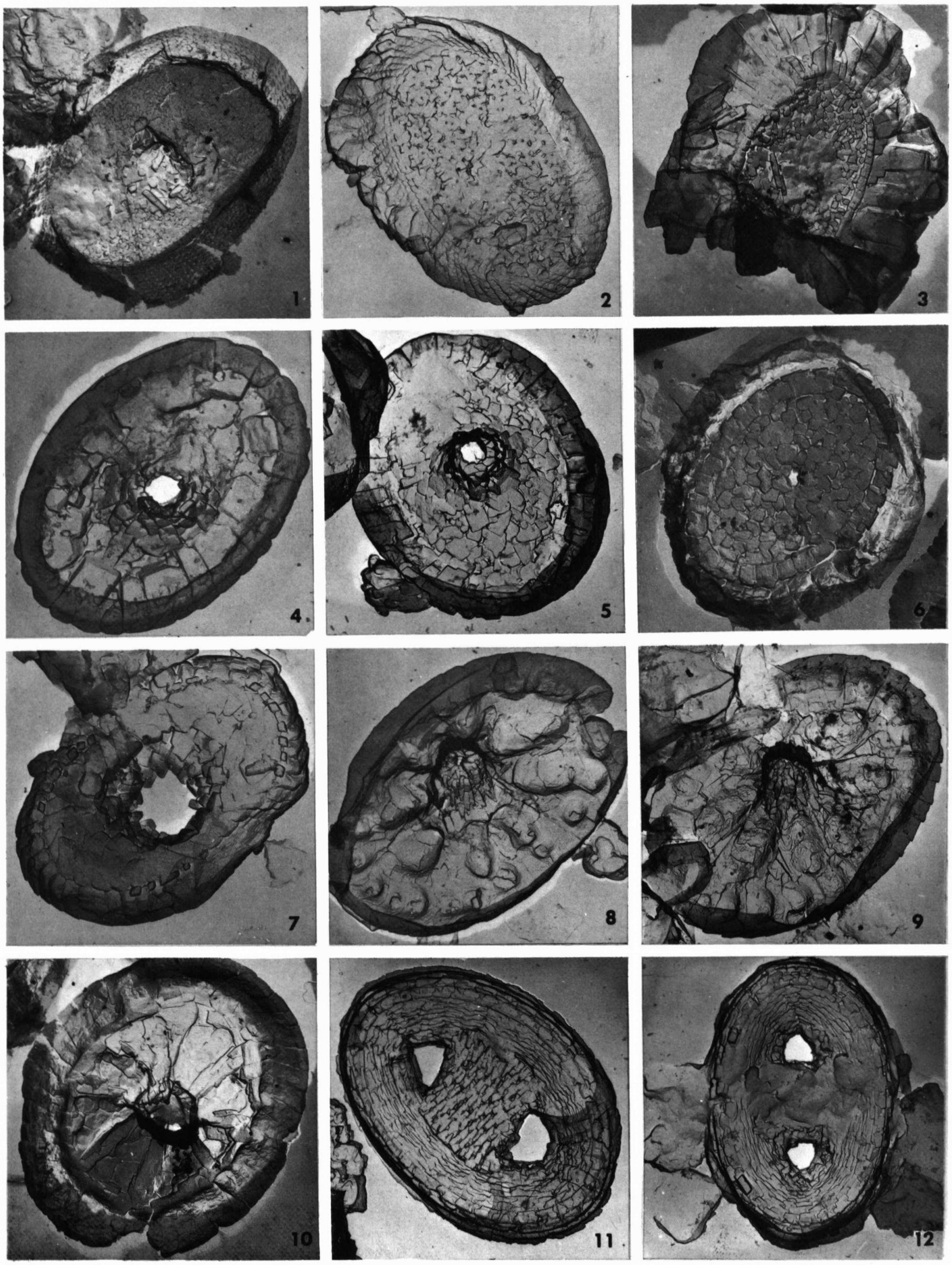
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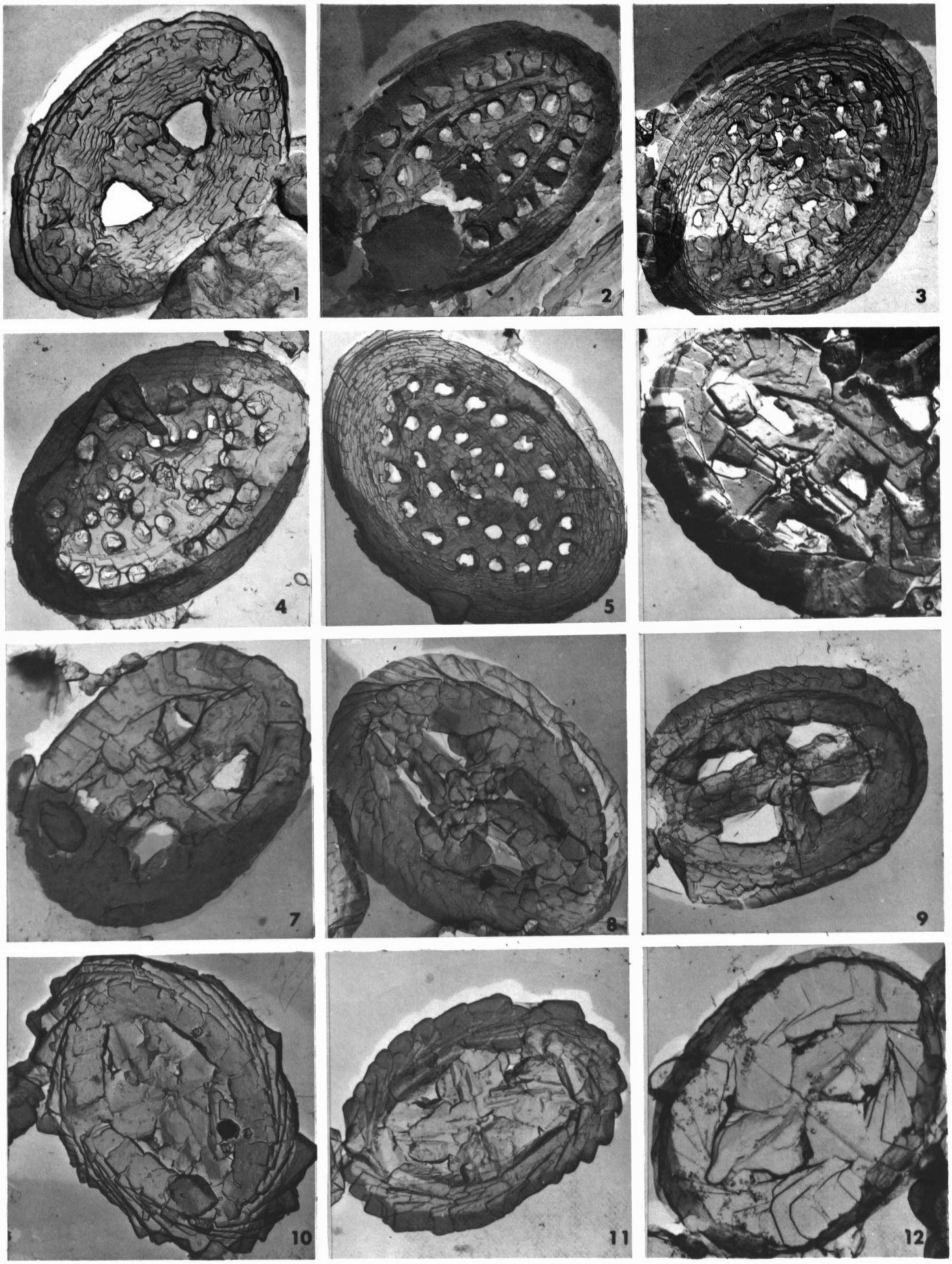
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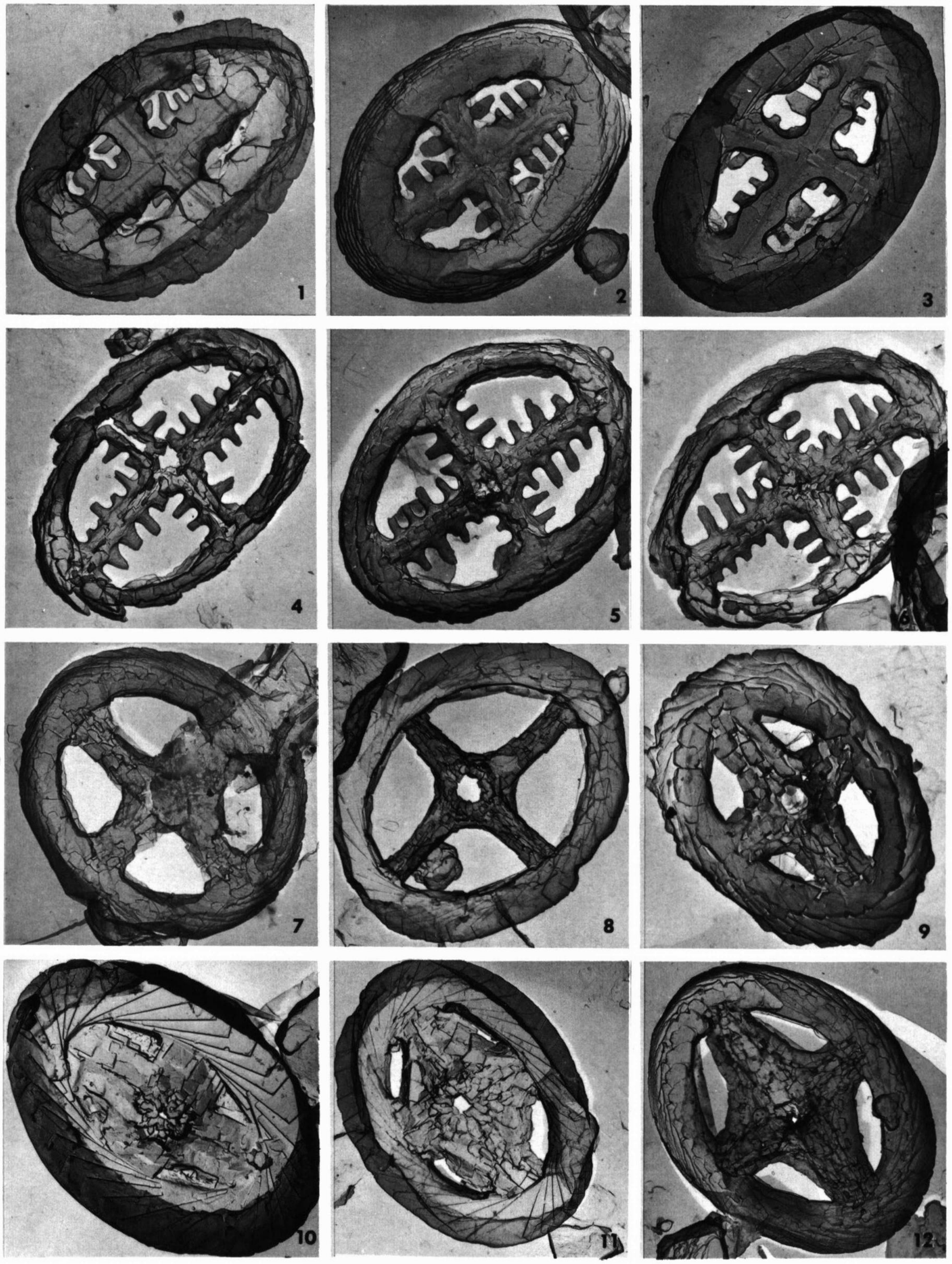
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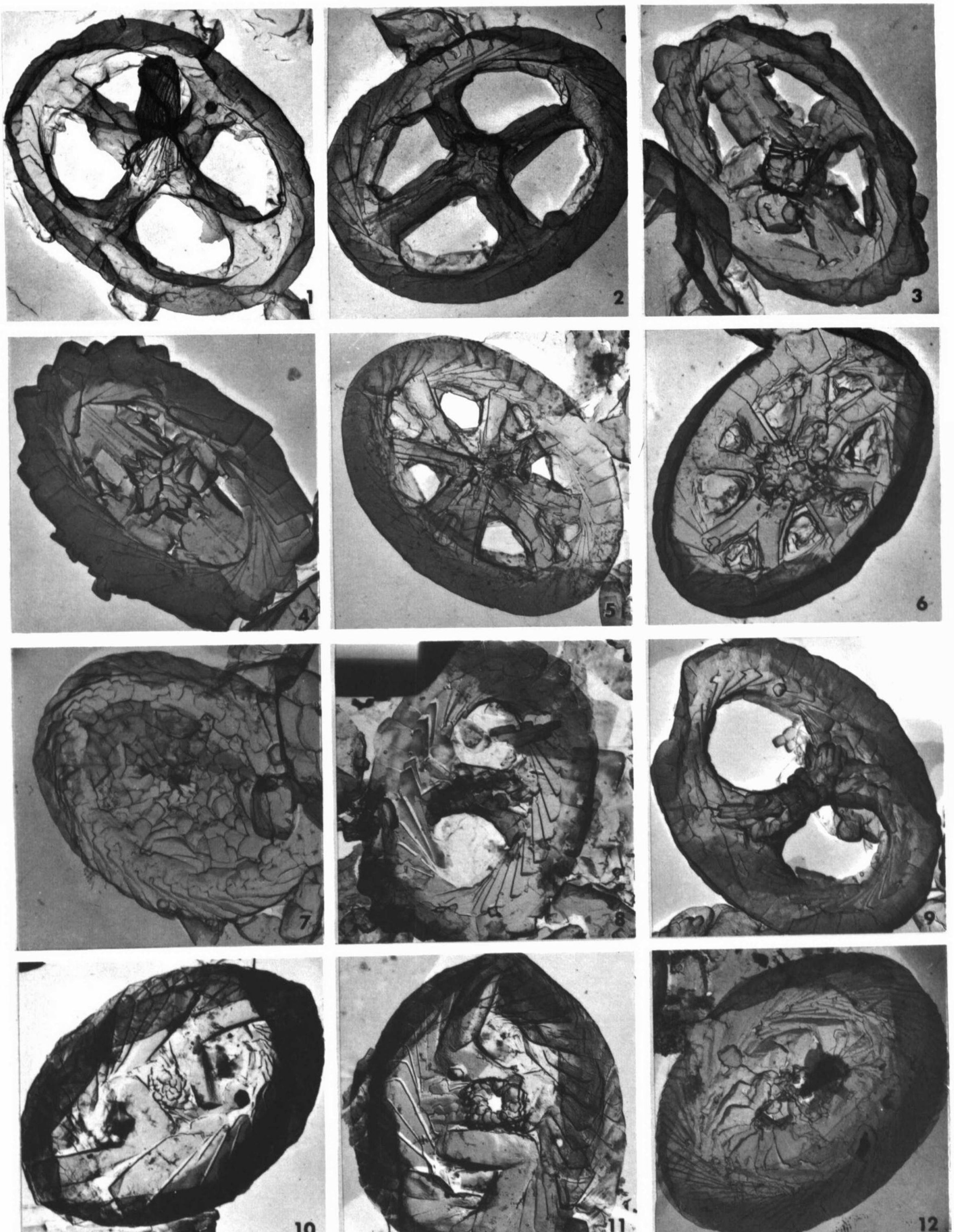
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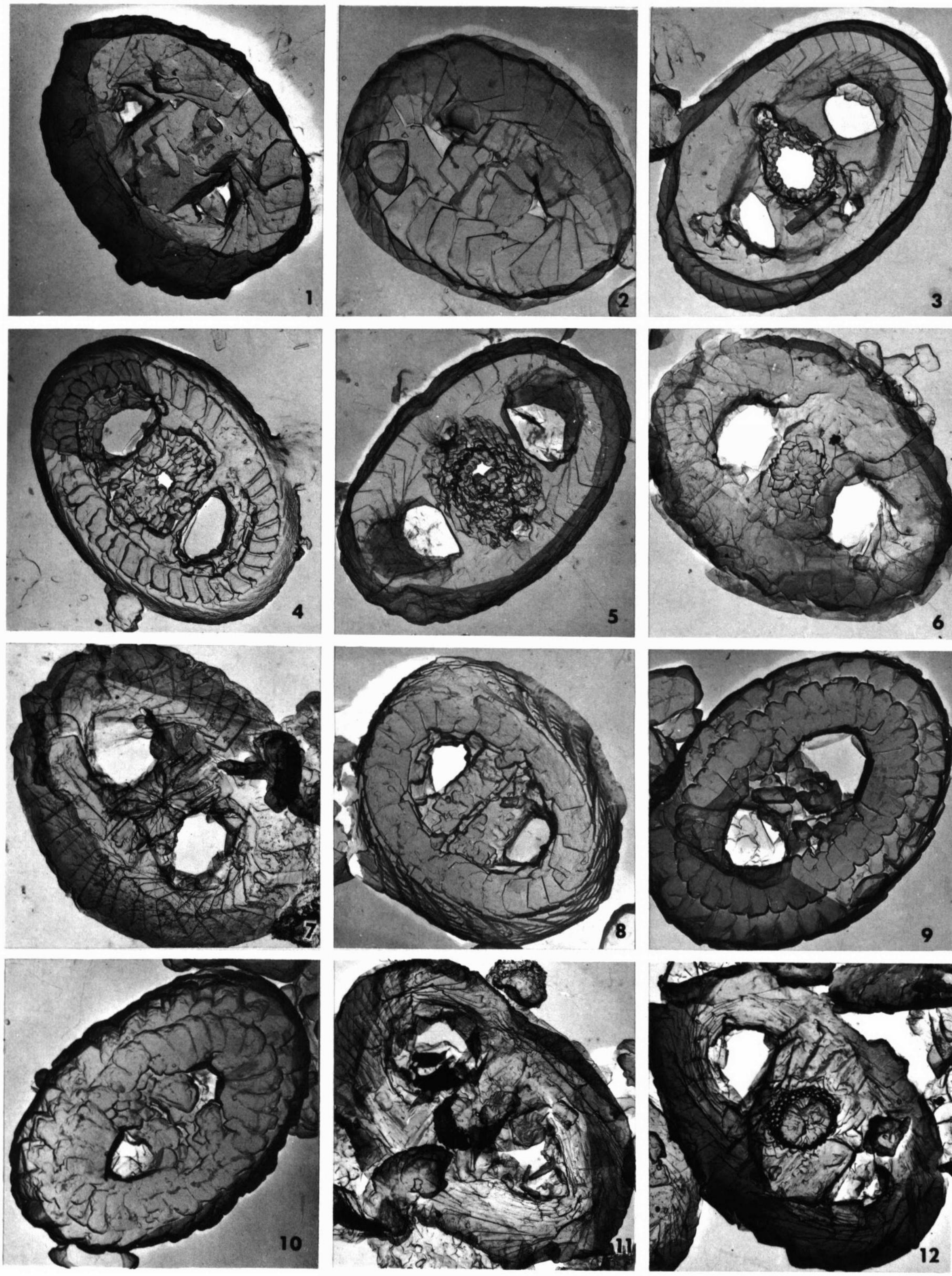
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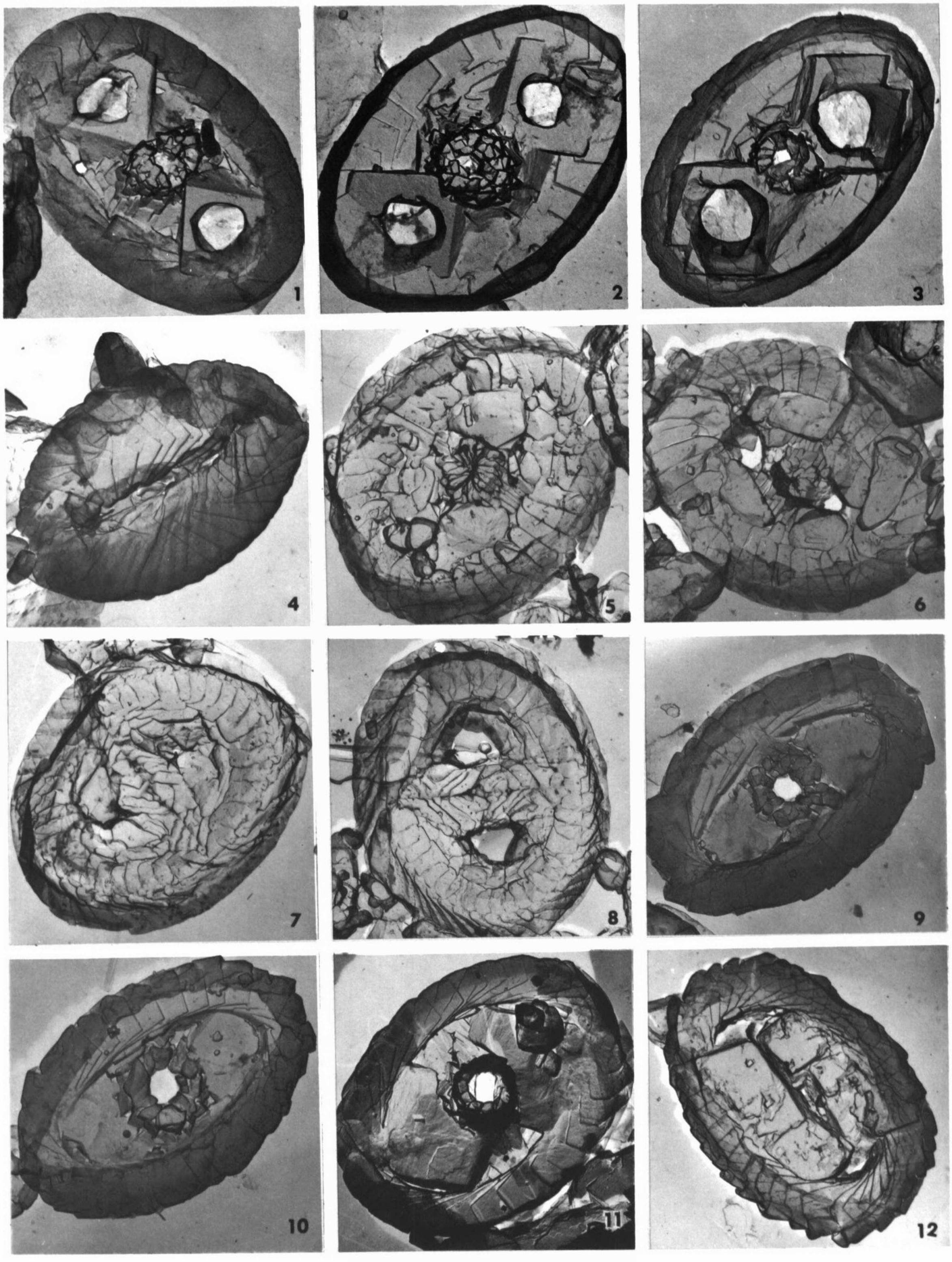
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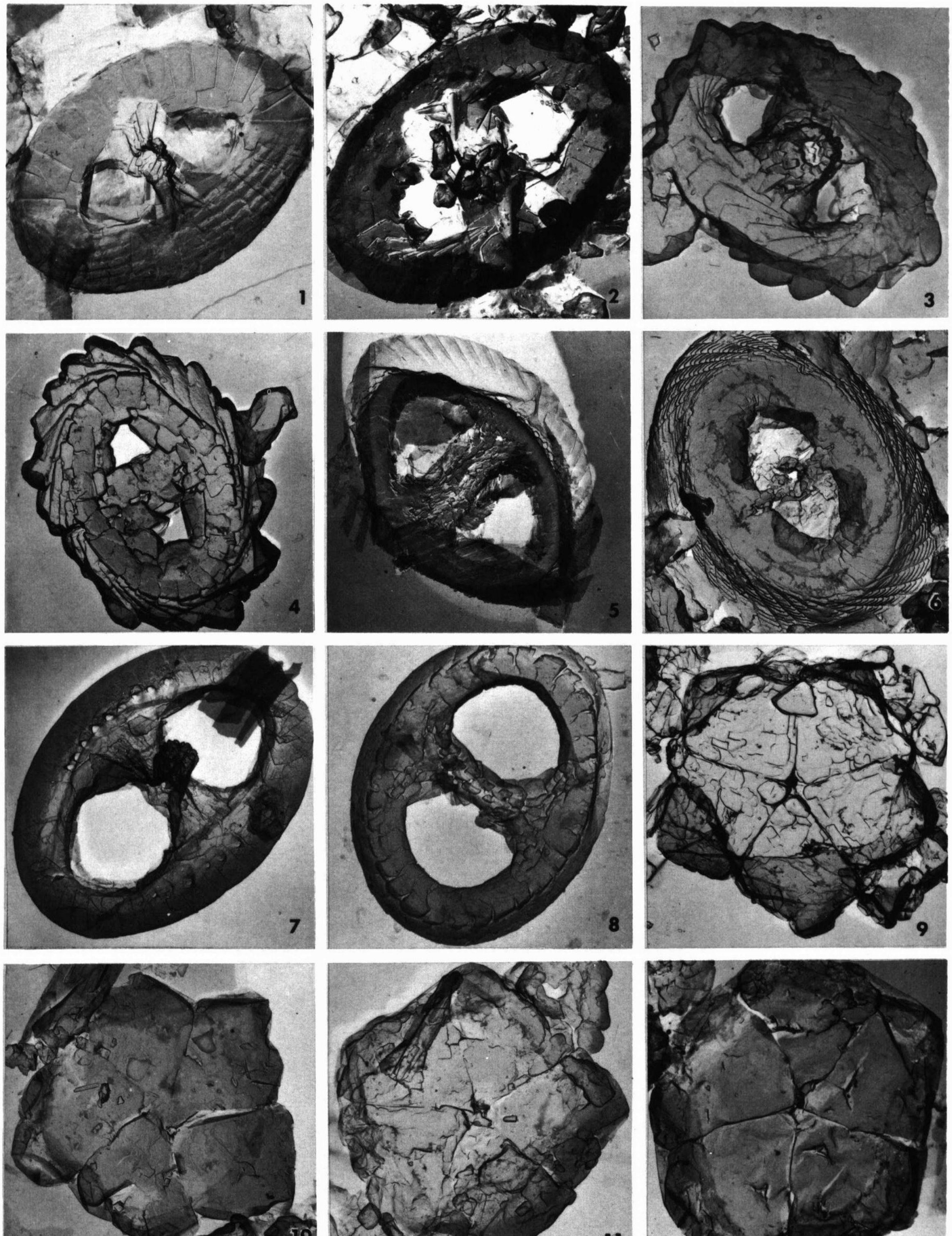

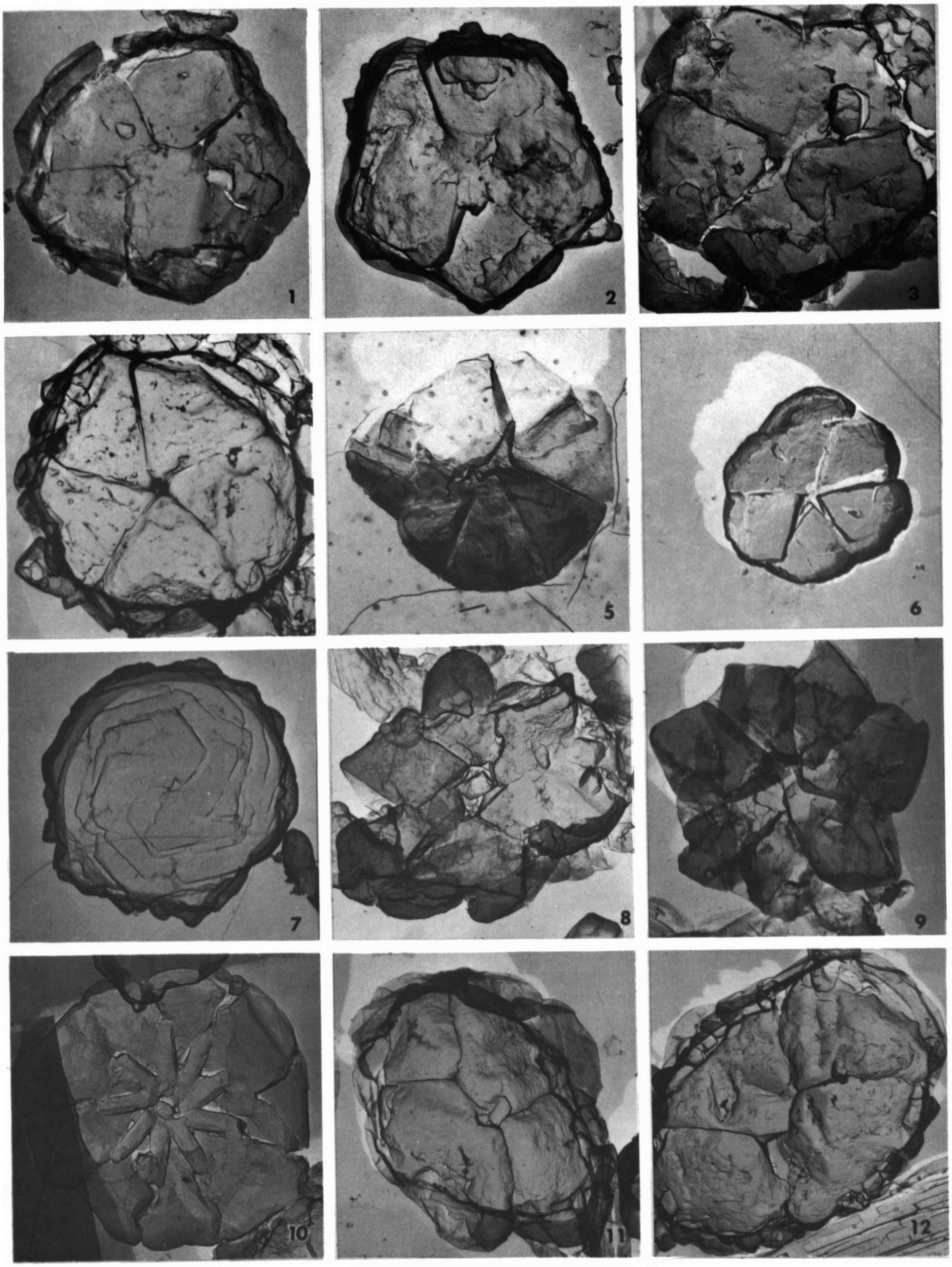
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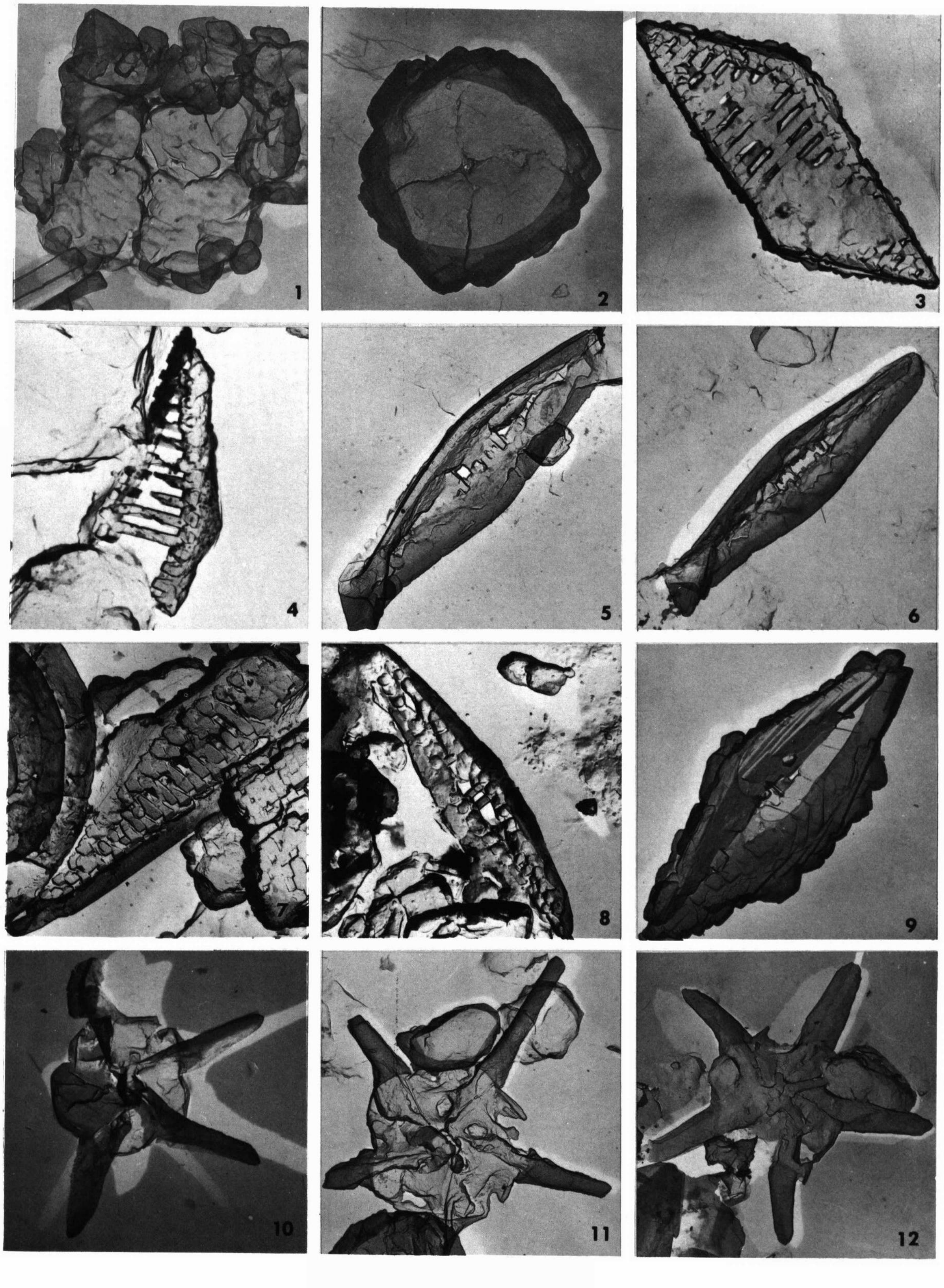
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